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STUDIES IN GUJARAT COTTONS, PART I

BY

MAGANLAL L. PATEL, B. AG

Cotton Supervisor, Gujarat

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CONTENTS

		Page
I.	General considerations	75
II.	*Goghari* cotton	
	1. History of *Goghari* cotton	81
	2. Characteristics of *Goghari* cotton	82
	3. Extent of admixture of *Goghari* with other cottons in Gujarat	86
	4. Has hybridization occurred among the various types of Gujarat *herbaceum* cottons?	88
	5. What characters are hereditary in *Goghari* cotton ..	92
	6. Description of certain pure line strains of *Goghari* cotton ..	100
	7. Comparison of strains of *Goghari* cotton with pure-bred *Broach deshi* cotton	115
III.	The ideal type of *herbaceum* cotton for Lower Gujarat ..	119
Appendix.	Certain morphological characters in *Gossypium herbaceum* ..	124

LIST OF PLATES

		Facing page
I.	A map showing the varieties of cottons grown in Gujarat ..	75
II.	A map showing the area under cottons in acres and its percentage to total cultivated area	76
III.	The method of opening of the bolls of *Goghari* cotton (Bolls with *kapas* and empty bolls)	82
IV.	Results of pulling apart from one another the seeds of a boll of *Broach deshi* and of *Goghari* cotton	83
V.	The seeds of *Broach deshi* and *Goghari* cotton and types of bolls in *Goghari* cotton	84
VI.	Comparison of the habit of growth of strain B3 (tall) and E5 (low) of *Goghari* cotton	103
VII and VIII.	Branches of *Broach deshi* cotton to illustrate the æstivation of the primary and accessory sympodia	124

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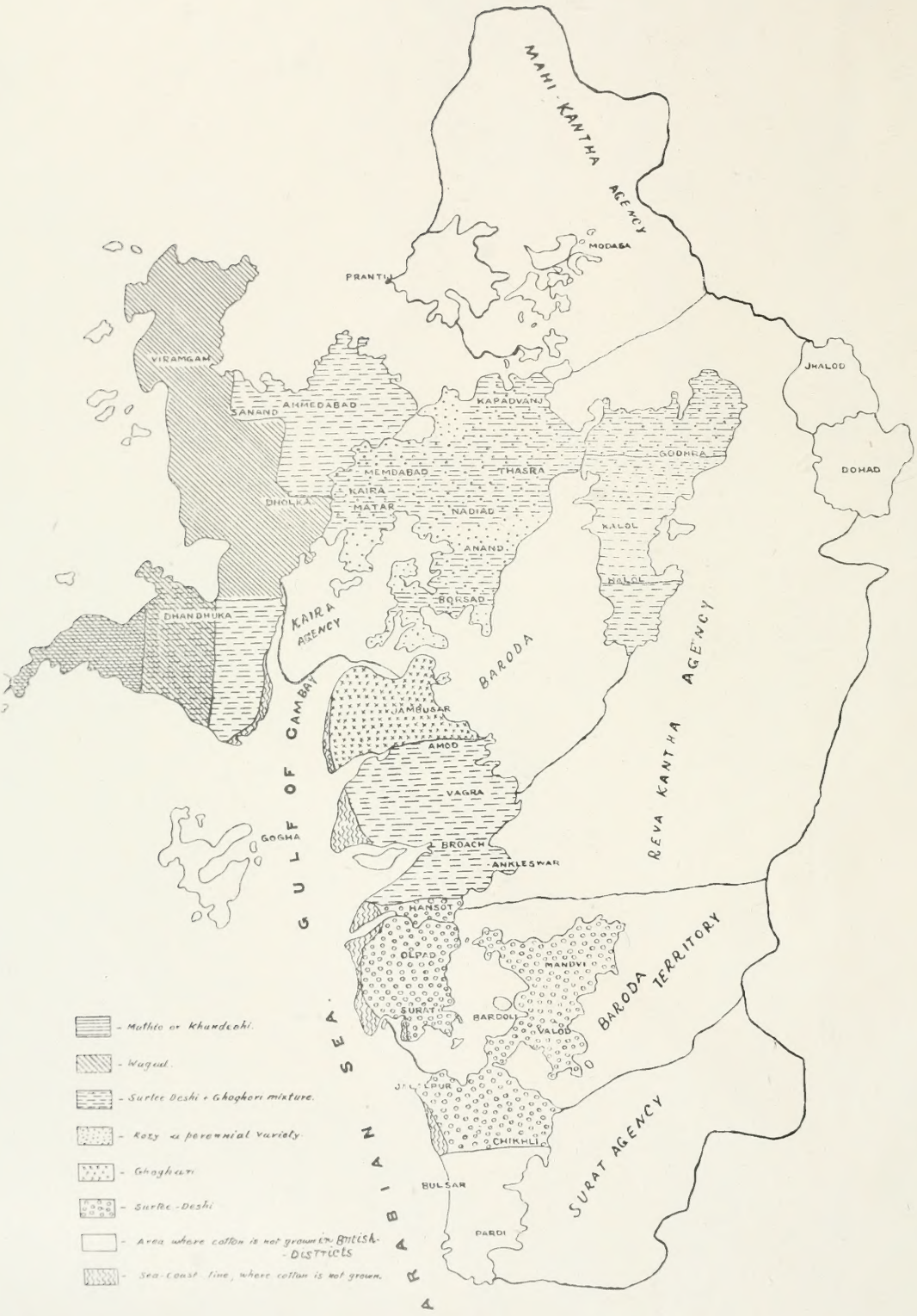


MAP OF BRITISH GUJARAT SHOWING VARIETIES OF COTTON GROWN.

STUDIES IN GUJARAT COTTONS, PART I.

BY

MAGANLAL L. PATEL, B.Ag.,

Cotton Supervisor, Gujarat.

[Received for publication on the 3rd September, 1920.]

I. General considerations.

Gujarat forms perhaps the most famous centre for Indian cotton growing. It has been renowned almost from the beginning of the Indian cotton trade, and so long ago as 1790, the annual production of Gujarat, including Bhavnagar, was 33,712,000 lb. or over 42,000 bales of our present measure, of which 26,656,000 lb. or over 33,000 bales were exported. Since that time the cultivation and production of cotton have extended, and Gujarat has become the home of two of the best known commercial types of Indian cotton, the " Broach " and the " Dhollera," and although, as we shall show, the cotton corresponding to these terms has varied very frequently and very largely, yet these names have for several generations indicated some of the best types of cotton that India has been able to produce. It is not, however, our intention in the present place to give a description of the history of Gujarat cottons and the types of plant which have produced them at different periods, but it will be necessary to review what is at present known of the varieties of cotton grown in different parts of the area, in order to make our studies of the individual types intelligible and clear.

The cottons grown in Gujarat at the present time belong to three different species: *Gossypium herbaceum*, which is by far the most extensively grown and which may be considered to give its character to the area, *Gossypium neglectum*, probably a recent introduction, grown to a considerable extent only in one corner of the area, and *Gossypium obtusifolium*, a perennial cotton grown sporadically over a large area of

Northern Gujarat, but the extent of whose cultivation is tending to decline. A map showing the varieties of cottons is attached herewith as Plate I. Plate II shows the area and the percentage of cotton area to the total cultivated area.

The variety of *Gossypium obtusifolium*, which is grown, as we have said, sporadically over a large part of the Kaira District and the northern portion of the Godhra Taluka in the Panchmahals, is locally termed "Rozi" or "Jadia" cotton. This type has been often described. Middleton[1] in 1895 characterized it as follows and his description fairly represents its special features :—

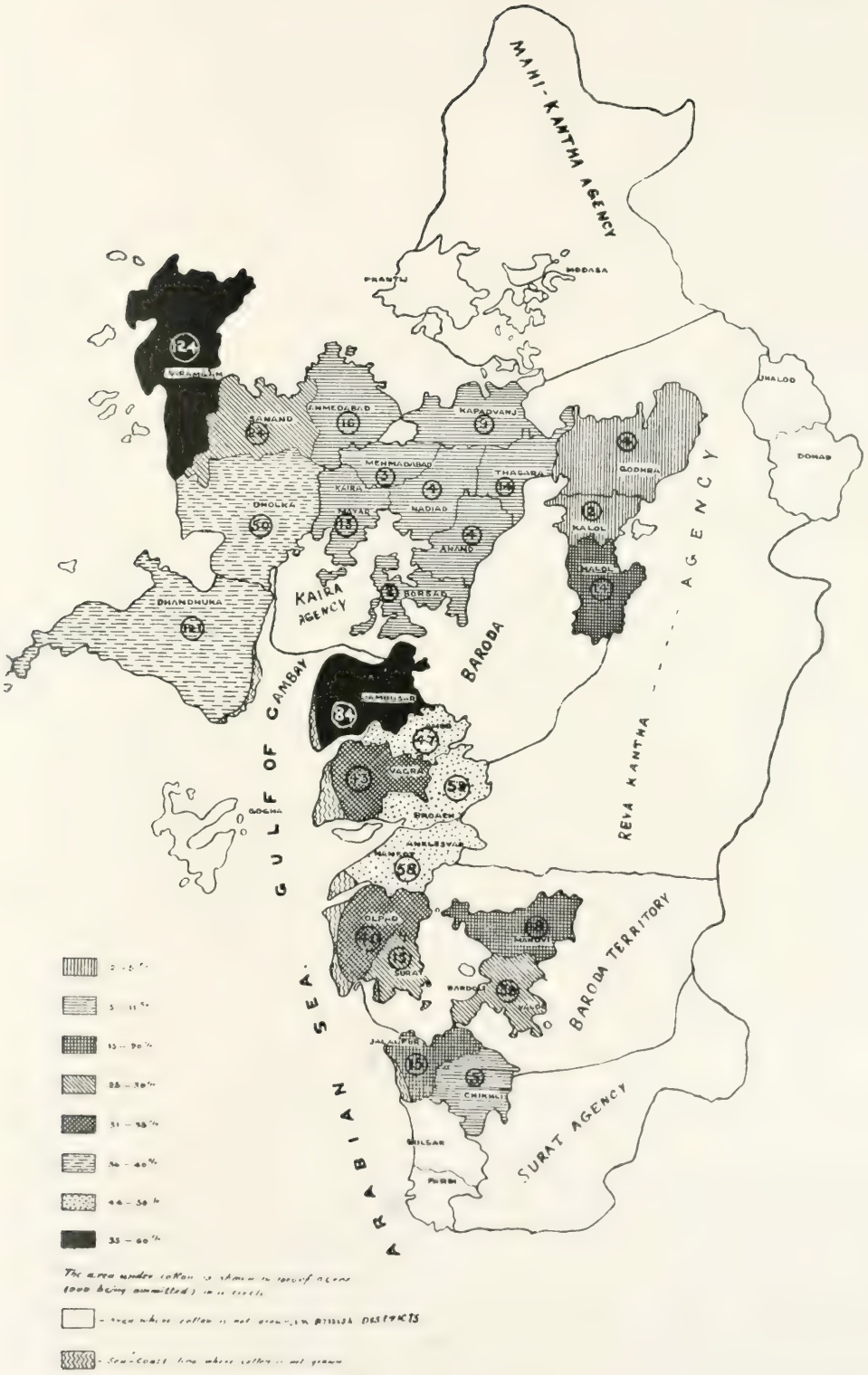
"This is a perennial, cultivated upon light soils in Northern Gujarat. A tall much branched shrub, 6 to 8 feet high, it readily runs wild, and in hedgerows assumes a climbing habit.

"This cotton is cultivated as a mixture crop, one row being sown between ten or twelve rows of some cereal. In the first season it yields little or no cotton: in the hot weather it is cut down to one foot of the ground, in the second monsoon it grows luxuriantly and produces a full crop in the following hot season. The cotton in subsequent years is of coarser quality than that of the second, and the plant is usually rooted out at the end of the third or fourth season, but it is occasionally allowed to grow for six or seven years. When growing wild in hedgerows the cotton turns yellow, and very short in staple ; the fuzz at the same time becomes long. *Rozi* is markedly different from the annual cottons and does not seem to hybridize with them. It strongly resembles *Gossypium arboreum*, the chief difference being a yellow flower and the absence of the marked reddish tinge possessed by this species."

As has already been stated, the cultivation of this cotton is declining. It produces a lint of fairly long staple, which is, however, very coarse, and is almost entirely used locally in Northern Gujarat. Its value is much decreased owing to the unripe condition in which it is usually picked. It has probably little or no future, and while it will continue to be grown, yet its cultivation hardly affects the larger interests of cotton growing in the province. It occupies nearly 7,000 acres in the Kaira District.

The type of *Gossypium neglectum*, which has in recent years extended over the greater part of Kathiawar, and especially of Bhavnagar, is known as "Mathio." In the British districts of Gujarat, it is found to any great extent only in the western portions of the Dhandhuka Taluka and the

[1] *Agricultural Ledger*, 1895, no. 8.



Map of British Gujarat showing the area under Cotton and the percentage of total cultivated area in 1916-17.

Gogha Petha of the Ahmedabad District. Its introduction seems to have been quite recent, and it has probably come from Khandesh. Prior to the great famine of 1899–1900, it was, according to Middleton[1], grown to a very limited extent in Bhavnagar, but its extensive adoption dates from about 1900. This adoption seems to have resulted from the fact that it will grow with less rainfall and in lighter soils than the varieties of *Gossypium herbaceum* formerly produced, and because it ripens earlier and hence enables the cultivators to realize their crop and pay their land revenue without recourse to a money-lender. Its extension, however, in the first years was slow, and it is barely mentioned by Gammie in his description of Indian cottons published in 1905. Since that time, however, its cultivation has increased enormously in Kathiawar, but it has been adopted only in the areas already mentioned in British Gujarat. Moreover, it does not show much sign of spreading further, as it is found that in the lighter soils of Northern Gujarat it has a tendency to ripen later, to decrease in ginning percentage and to yield less than *herbaceum* cottons under irrigation. The actual portion of British Gujarat which it occupies is shown in Plate II, where its area is 27,000 acres. It rarely occurs as a mixture in the field, except to a very small extent, with *Wagad* and *Lalio* cotton (*see* below).

But by far the greater part of Gujarat is cultivated with various varieties of *Gossypium herbaceum*, and it is to this species that its cottons owe their special reputation and character. The description of these varieties, their characters, and the areas they occupy, is, however, in considerable confusion, and nearly every authority seems to have adopted a different arrangement of them. We shall take as the basis of the following short account, the descriptions given by Gammie in 1903. He first divides the types of *Gossypium herbaceum* occurring in Gujarat into two groups as follows :—

"*Section A.* Bolls spherical, with broad valves, splitting so slightly when ripe that the cotton does not emerge. *Wagad* or *Wagadia* and *Sakalio*, five to six feet in height, cotton copious, but rather coarse, staple $\frac{5}{8}$ inch. Bolls with a very short point, but occasionally narrowed into a long one, mostly three-celled, dimensions average one inch by one inch.

"*Section B.* Taller and more compact plants than in the first section ; bolls more distinctly trigonous, narrower and pointed. Valves of ripe boll strongly reflexed so that the cotton is pendulous : bracteoles not so distinctly spreading

[1] *Agricultural Ledger*, 1895, no. 8.

"*Lalio, Kanmi.* Bolls $1\frac{1}{4}$ by $\frac{7}{8}$ inch, cotton fine, adhering only slightly to seed, staple $\frac{5}{8}$ inch.

"*Kumpta, Broach.* Size and habit of *Lalio*, but more hairy, and some of the bolls rounder but smaller, $1\frac{1}{8}$ by $\frac{5}{8}$ inch.

"*Goghari*, similar in most respects to *Wagadia*, but the plants are more spreading and the bolls open out like those of *Lalio.*"

It is needless to follow the various modifications of the classification which have been given by different writers, but if we put together the essential facts as given by each of them, and combine them with our observations, we can indicate the following three clearly distinct types now cultivated in Gujarat :—

1. *Wagad* (*Wagadia, Dhumadia, Sakalio, Dabalio*) is a small branched bush, usually standing eighteen to thirty inches high, much less hairy than *Broach deshi.* The young stems, petioles, etc., are moderately thickly covered with simple hairs. Stellate hairs are large and numerous on the young leaves, few on the older leaves, which are almost glabrous and have a shining oily appearance. Stems, branches and petioles are of a deeper red in the upper surfaces than with *Broach deshi.* Leaves three to five lobed, cordate, half segmented or less. Lobes ovate to broad ovate, constricted at the base ; the lobes of the leaves on the younger branches are broad, obtuse, leathery and not constricted at the base. The spreading habit of the bracteoles is seen in all the annual cottons of Gujarat, but is most marked in *Wagad*, where they often begin to spread when the flower is opening. Bolls are smooth, globose usually, but sometimes tapering, mostly three-celled, and do not open fully when ripe, so that they are forced open by hand when removing the *kapas.* The lint is dull, white and coarser than *Broach deshi* and about equal in staple to the latter.* The seeds are rather large in size, oval in shape with a distinct hook at the tip, five to eight per cell and covered with fuzz.

The primary fruiting branches are stronger in *Wagad* than in other types of *herbaceum* cotton, while the axillary limbs develop later. Hence a larger proportion of the bolls are borne on the primary fruiting branches than in other Gujarat varieties. *Wagad* is the earliest flowering *herbaceum* but the flowering lasts a very long time, and the ripening is slow. The plant requires less moisture than the other varieties, and takes eight months to ripen. It is grown on slightly saltish land and its distribution in Gujarat reflects this feature. In British Gujarat, it nearly occupies 248,000 acres.

2. *Broach deshi* (*Lalio*) is a small shrub usually three to four feet high but varying greatly in size according to the soil. The whole plant is

*Most of the description is taken from Middleton (*loc. cit.*).

generally hairy, the young leaves and bracteoles pubescent, hairs stellate or three to four branched. The petioles, leaf ribs and peduncles villous, hairs simple, though a few stellate or branched hairs occur on the ribs. The leaves are very variable, cordate. The lower and larger leaves are five, six or seven lobed, the upper leaves three to five lobed, half or less than half segmented. The middle lobe is ovate, acute, mucronate and constricted at the base. The stipules are persistent, linear, and those in peduncles markedly unequal, one of them oblique, secondary or tertiary ovate, truncate, toothed and the other lanceolate-acuminate. The bolls are not usually smooth, of all shapes, usually three-celled, seldom two or four-celled, and they open fully when ripe, the valves being highly recurved on the edges. The lint adheres loosely to the seed, and is fine creamy-white, silky and of good staple. The seeds are smaller than in *Wagad* cotton and covered with whitish fuzz, usually six to seven per cell, seldom eight to ten.

So far as the branching is concerned, the limbs are more developed than in *Wagad*, and the axillaries arise earlier and are more numerous than in the latter variety. The flowering characters vary very largely, but the flowers appear later than in *Wagad* though the flowering is over sooner.

3. *Goghari* only differs from *Broach deshi* as regards the boll characters, and those of the seed and lint. These are described fully later as given by Middleton (page 81) and as observed by me (page 83).

These three types are the only ones which can, we think, be distinguished among the *herbaceum* cottons of Gujarat. They will be found mixed and hybridized in every proportion in almost every part of the province, and it is comparatively rare, except in very restricted areas, to find any of them in a perfectly pure condition. The *Wagad*, however, can be found relatively pure in a tract lying to the extreme north-west of British Gujarat in the Ahmedabad District, and on the borders of Kathiawar. The best centres for getting pure *Wagad* cotton are, perhaps, Viramgam and Bavla. Again the only centre where *Broach deshi* can now be found relatively pure is in certain parts of the Surat District in the extreme south of the cotton area of Gujarat. The best centres for getting pure types are Jalalpor, Vedchha and Bilimora. The third variety, the *Goghari*, is found in the purest condition in the northern part of the Broach District, in the Jambusar Taluka. All the rest of Gujarat grows a mixture of types, and this is sometimes called *Kahanma* or *Kanri*, sometimes *Broach*, sometimes *Lalio*, sometimes *Imli*, while there are dozens of other local names. Its characters vary with the extent of the mixture and of the constituents. Until recently *roach deshi* decidedly predominated

everywhere, but in the last few years the extent of the mixture with *Goghari* has generally increased. The Indian Cotton Committee record the following proportions in the mixture in different areas :—

District	* Percentage mixture of		
	Wagad	*Broach deshi*	*Goghari*
AHMEDABAD			
(1) Dhollera (*Lalio*)	10·7	89·3	..
(2) Do. (*Wagad*)	90·0	10·0	..
(3) Sanand (*Lalio*)	2·7	97·3	..
(4) Do. (*Wagad*)	87·0	13·0	..
(5) Viramgam (*Deshi*)	100·0	..	..
(6) Do. (*Lalio*)	..	41·7	58·3
KAIRA			
(7) Thasra (*Kahanmi*)	..	60·8	14·2†
(8) Mehmadabad Do.	..	54·8	45·2
(9) Matar Do.	..	52·2	47·8
PANCHMAHALS			
(10) Kalol (*Kahanmi*)	..	48·6	
BROACH			
(11) Ankleswar (*Deshi*)	..	63·6	36·3
(12) Jambusar (*Goghari*)	..	7·9	92·1
(13) Broach (*Deshi*)	..	52·4	47·4

In spite of this condition of hopeless mixture, the three types can be traced throughout, and though hybridized and rehybridized again and again the plant and produce can always be referred to one or other of the descriptions given above.

It would be interesting to connect the proportion of these three types of *herbaceum* cotton with conditions of climate and soil, but though a few general indications can be given. the time is not yet ripe nor our inquiries sufficiently advanced to come to any but the most provisional conclusions in the matter.

In the first place, however, it is fairly clear that *Wagad* cotton dominates the situation only where the soil has a tendency to be saltish and where the rainfall is likely to be deficient. The soil may be either heavy or light. It is stated, though it is not equally certain, that the tracts, which grow *Goghari* best and where it yields more highly than any other variety of *herbaceum* cotton in Gujarat, are, where the soil is moderately light, of a

* The terms used by the Cotton Committee have been modified to suit our classification.

† Also contains 25 per cent Rozi cotton.

besar or *goradu* type with a deep subsoil. But *Goghari* seems extremely adaptable, and is capable of flourishing, as well as *Broach deshi*, over the greater part of Gujarat, as is illustrated by its general extension in recent years.

II. Goghari cotton.

1. *History of* Goghari *cotton.*

Goghari cotton, the extension of cultivation of which in Southern Gujarat, has been so disastrous for the quality of the staple in this part of India, has only been recognized as a separate type in very recent years. Where it came from we do not know. Its name would suggest that it originally was brought from Gogha, a part of the Ahmedabad District in Kathiawar, to the south of Bhavnagar, and that from there it may have been carried across the Gulf of Cambay to the Jambusar Taluka of the Broach District, where it is now grown in its purest form. But of this there is no direct evidence, and the first notice of this cotton occurs in 1891. In that year in a communication to the Bombay Trades Association[1] the following statement was made :—

"The only foreign seed introduced in Broach was the *Goghari* seed. That seed has been brought into Broach District during the last fifteen years, and the cotton produced from that seed was of an inferior quality. His firm first sent a consignment of this cotton home ; it was reported upon as harsh, deficient in staple, but of good colour and fine class. But since the *Goghari* seed has been acclimatized, the result was that the *Goghari* (seed) cotton had been passing in Liverpool as fine machine-ginned *Broach*, with an allowance of 1/32*d*. to 3/32*d*. per pound of the class, but when shipped as *Fully Good Broach* with mutual allowance terms, it fetched 1/8*d*. to 3/16*d*. per pound on the class sold. This *kapas* paid the *raiyat* because the lint outturn was better."

A few years later the variety was definitely established as a recognized type of cotton cultivated in the northern part of the Broach District. Middleton[2] in 1896 describes it as follows :—

"In *Goghari* the bolls are globose, and larger than those of *deshi*.* The segments of the capsules are broad and do not recurve when the fruit is ripe. The lint hairs surrounding each seed separate readily from those of the

[1] Extracts from the *Proceedings of the Cotton Trades Association*, July 31, 1891 : Communication by Messrs. Narandas Rajaram & Co.

[2] *Agricultural Ledger*, 1895, no. 8.

* By *deshi*, ordinary *Broach deshi* cotton is meant.

adjoining seed, and do not cling as in *deshi*. The seeds are larger and darker in colour and have more fuzz. The wool (*i.e.*, lint) adheres more firmly to the seeds, is whiter, crisper, coarser, and more abundant. It is supposed to be a cross between the two cottons of *herbaceum*, namely, *Broach deshi* and *Wagad*. *Goghari* and *Broach deshi* seem to cross readily, and plants intermediate between the types are very common.

"*Gundi Goghari* plants are smaller with numerous bolls. The cotton is better in quality than is *Goghari* proper. This is believed to be an intermediate form between *Goghari* and *Kahanmi*."

Some of these statements seem equally true to-day. In other matters the cotton seems to have considerably changed its character. We will, however, indicate a little later in what ways the present day typical *Goghari* cotton differs from what Middleton describes.

Eight years later Gammie[1] published his description and classification of the Indian cottons, but the following is his only reference to this variety :—

"It is similar in most respects to *Wagad*, but the plants are more spreading and the bolls open out like those of *Lalio*."

In a later report[2], however, he states that *Goghari* exists as an appreciable mixture in *Broach*, but not in *Surat* cotton. In the neighbourhood of the Broach District, he quotes a case where *Goghari* occurred to the extent of 14 per cent. in the mixture grown.

He says, moreover, that "in *Goghari* the seed is larger than that of *Broach deshi*, and the cotton is more adherent so that it is more difficult to gin. The fuzz is white while that of *deshi* is brown." We will consider later how far these observations agree with ours.

2. *Characteristics of* Goghari *cotton.*

None of these references to *Goghari* cotton had hitherto given a really recognizable description of the variety with which we are dealing. It is, however, very distinct, and in the relatively pure form in which it occurs in the Jambusar Taluka of the Broach District it can be recognized easily when growing, after the bolls have opened, and also in the seed cotton or even in the seed. So far as the plant itself is concerned, a critical study for a number of years has, however, failed to indicate any constant feature by which *Goghari* plants can be distinguished from ordinary plants of *Broach deshi* up to the time of the opening of the bolls. The form and branching of the plants (and the form of the leaves) are similar, the manner

[1] The Indian Cottons, 1905.

[2] *Report of the Imperial Cotton Specialist*, 1914-1915.

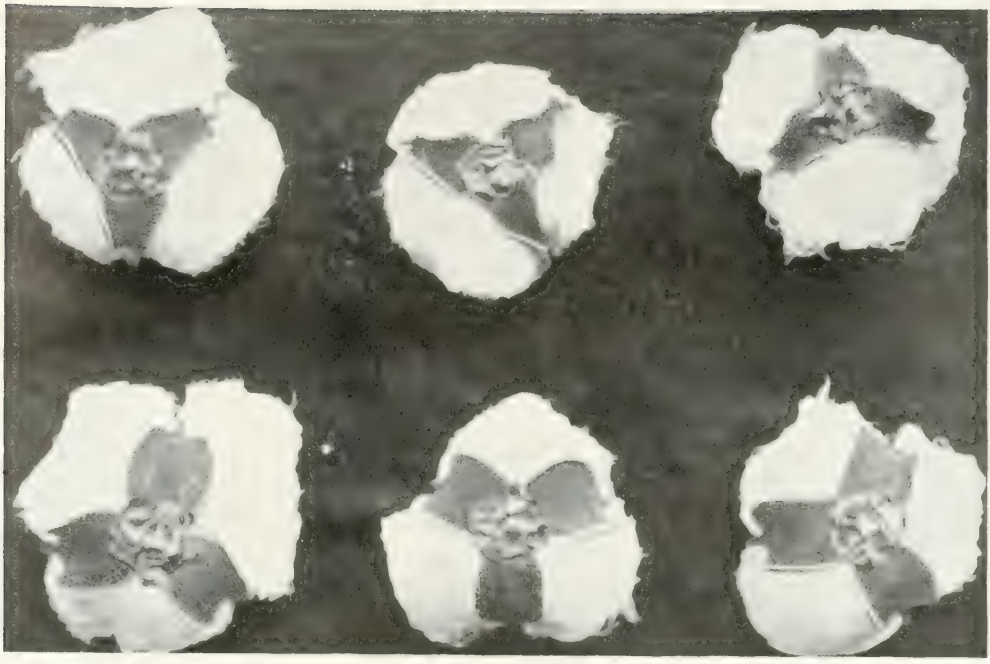


Fig. 1. *Upper row.* Broach Deshi, showing the recurving at the sides giving wide opening, due to which the cotton hangs down.

Lower row. Goghari, showing no recurvature, thus having less wide opening.

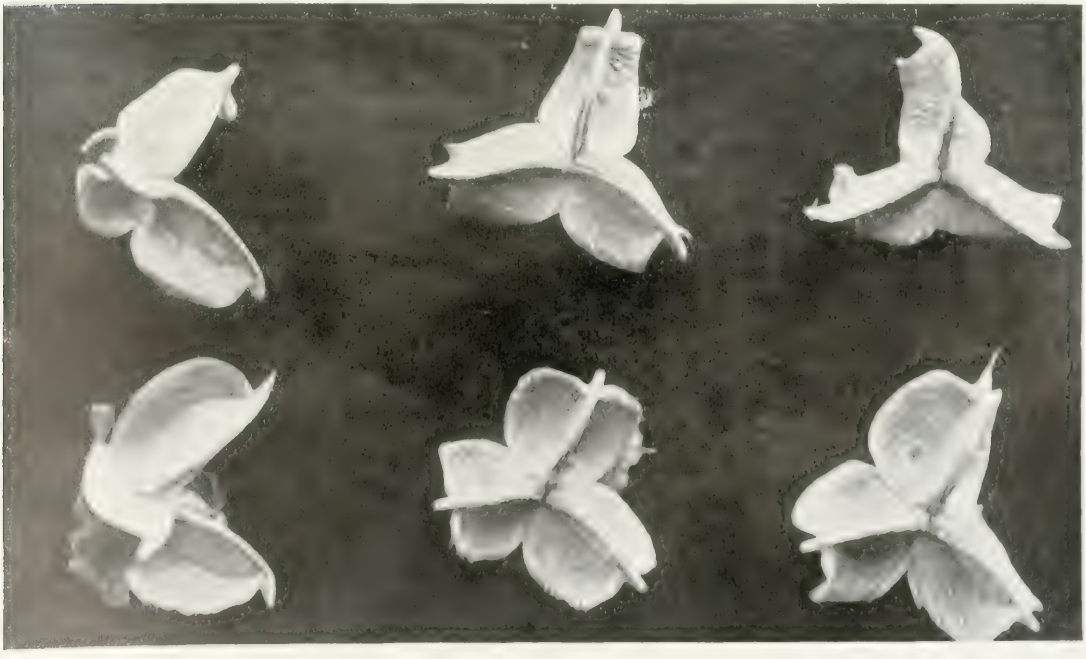
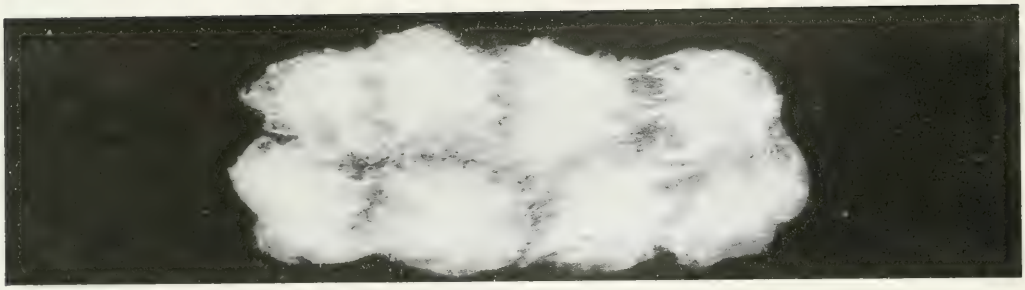
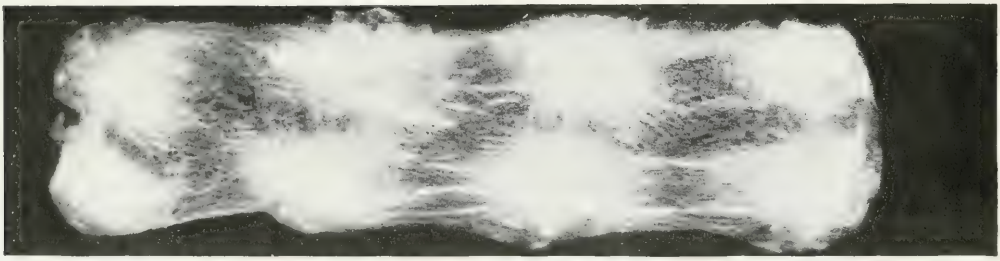


Fig. 2. *Upper row.* Surtee Broach Deshi. 1, side view, having the horizontal septa and the middle angle broad; 2, 3, horizontal views having the recurving on the sides.

Lower row. 1, side view, having the perpendicular septa forming the middle angle acute; 2, 3, horizontal views having no recurvature.





Above. Kapas from the cell of a boll of Goghari showing the length to which each seed with lint hairs can be drawn from the other without perfect separation. This is probably due to the shortness and roughness of the staple.

Below. Kapas from a cell of a boll of Broach Deshi showing the greater length to which each seed with lint hairs can be drawn from the other without complete separation. This is probably due to a long and silky staple.

of flowering and the character of the flowers are the same. All the types of bolls found among *Goghari* are also found among *Broach deshi* cottons (Plate V, fig. 2), and there is no evidence for the statement of Middleton that the bolls are globose and larger than those of *Broach deshi*. But as soon as the bolls open the characteristics of the variety appear. These are three in number.

1. The opening of the bolls is strikingly different in *Goghari* cotton from that of *Broach deshi*. In the latter cotton the edges of a cell of a boll recurve when fully open; in *Goghari* this never occurs. (Plate III, fig. 1.)

As a result, the angle between the septa in the shell of the completely opened boll is greater in the case of *Broach deshi* than in *Goghari*. (Plate III, fig. 2.)

2. The *kapas* in the two cases differs in the ease with which the seeds can be separated from one another. In *Goghari*, as has been already pointed out by Middleton, the lint hairs surrounding each seed separate readily from those of the adjoining seeds and the seeds do not, therefore, cling together by means of the lint hairs in the manner which is characteristic of *Broach deshi* cotton. This can be seen in Plate IV. The difference is probably due to the lint hairs in *Goghari* being shorter and thicker than in the other variety.

At the same time the lint adheres much more firmly to the seed than in *Broach deshi* cotton. This can be indicated, somewhat roughly, by the relative time taken to hand-gin *kapas* of the two types.

	Goghari		*Broach deshi*	
	Hours	Minutes	Hours	Minutes
Time taken to gin 1 lb. *kapas* ..	1	14	0	34
Time taken to obtain 1 lb. lint ..	2	43	1	40

3. The seed, after ginning, in *Goghari* cotton usually retains a large number of torn lint hairs, showing the force required to separate them from the seed. As a result most of the previous writers on the subject, including Middleton, have stated that the seed bears more fuzz than is found in the case of *Broach deshi* cotton. Precisely the opposite is really the case, and if the torn lint hairs are removed by forceps, it is easily seen that the *Goghari* seed really presents an almost clean darkish testa without fuzz. The difference can be seen clearly in Plate V, fig. 1.

These differences render it easy to distinguish in the case of any ripening plants, or in the case of any collection of *kapas* or cotton seed whether we have to do with *Goghari* or *Broach deshi* cotton, and enable the proportion of

each in a mixture to be determined. In addition to these characters by which *Goghari* cotton can always be detected, there are certain general commercial differences which distinguish any lots of the two types of cotton which may be placed on the market. These are as under :—

1. The lint in *Goghari* cotton is shorter than in *Broach deshi*, and this is practically universally the case among all the strains of each kind that have been examined. The attached table and graph (p. 85) show the frequency of different lengths of staple in an average pure strain of each variety, the lint being taken from the middle of the seed.

	Goghari	*Broach deshi*
	Percentage of cases	
cm.		
1·5 — 1·6	1	..
1·6 — 1·7	10	..
1·7 — 1·8	6	..
1·8 — 1·9	8	1
1·9 — 2·0	22	1
2·0 — 2·1	20	2
2·1 — 2·2	22	4
2·2 — 2·3	10	6
2·3 — 2·4	1	15
2·4 — 2·5	..	16
2·5 — 2·6	..	17
2·6 — 2·7	..	21
2·7 — 2·8	..	8
2·8 — 2·9	..	8
2·9 — 3·0	..	1

Though, therefore, there may be seeds among a sample of *Broach deshi* cotton which bear lint hairs shorter than those found in *Goghari*, yet in practically every case the average staple is shorter in the latter than in the former, and so far no strain of *Goghari* has been evolved or selected which has an average staple as long as even the lower types of *Broach deshi* cotton.

2. The ginning percentage, or in other words the proportion of weight of lint to weight of *kapas*, is much higher in the case of *Goghari* cotton than in the case of *Broach deshi*. It is this quality which has caused the large extension of the growth of *Goghari* cotton, and we may illustrate the difference between the two types we are comparing by a table showing

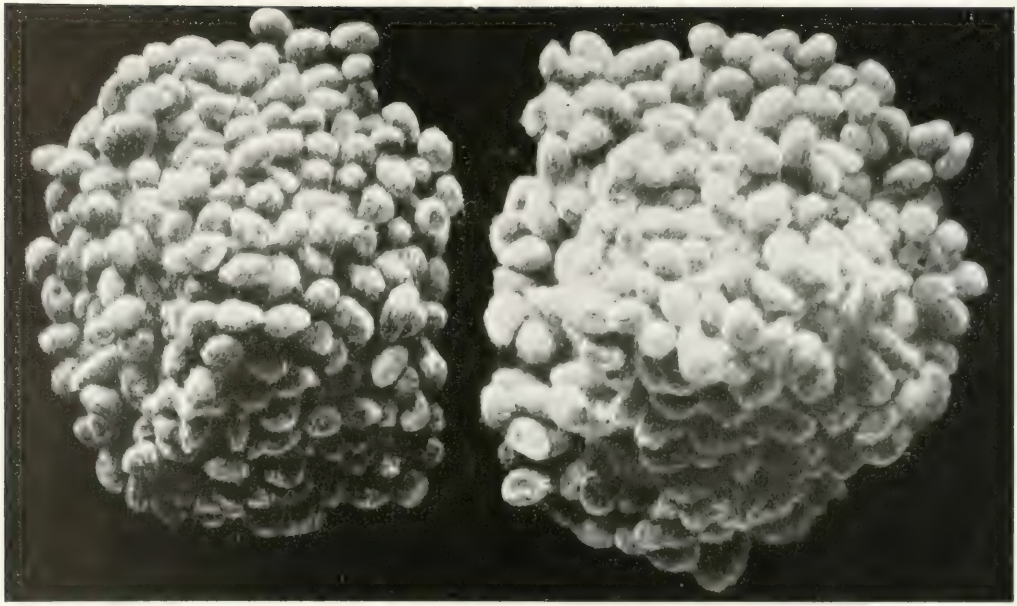


Fig. 1. ***Left side.*** Seed of Goghari almost naked (*i.e.*, without fuzz).
Right side. Seed of Broach Deshi so fuzzy as to present the velvety white surface all along.

Fig. 2. A, Boll spherical in shape and bigger in size than C;
B 21, Boll distinctly tapering;
B 3, Boll tapering, surface rough (tall type);
C, Boll spherical but smaller than A;
E, Boll intermediate in shape between spherical and tapering.

the ginning percentage of a number of average samples of each kind purified and grown side by side.

	Ginning percentage of	
	Goghari	*Broach deshi*
(1)	44·5	37·7
(2)	41·6	36·8
(3)	42·3	38·4
(4)	41·8	35·4
(5)	43·8	32·3

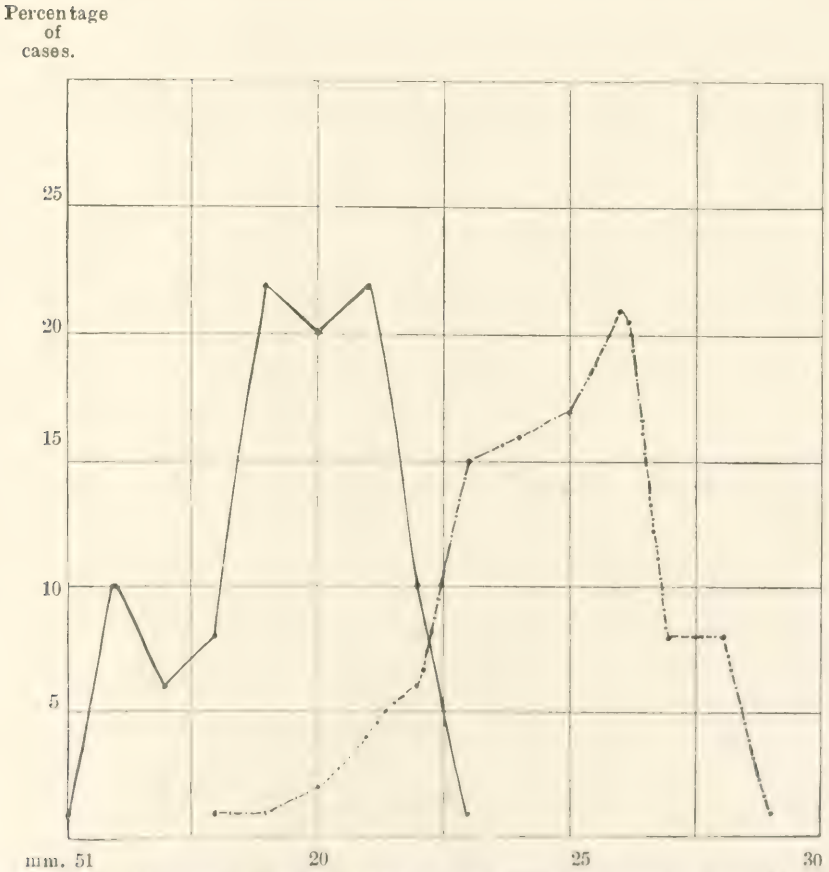


FIG. 1. Variation in length of staple on the middle of the seed in *Goghari* (–) and *Broach deshi* (.—.—.).

The difference in this respect is, hence, very considerable, and though there are strains of *Broach desha* cotton, which we have isolated, with a

ginning percentage higher than that of the poor strains of *Goghari*, yet the difference indicated by the above figures is maintained in the commercial lots of *kapas* in a remarkable manner, and is the basis for the high valuation of this *kapas* in the market.

Such are the differences between the two types of *herbaceum* cotton which are grown in Southern Gujarat, and the special characteristics of *Goghari* cotton which have given it a definite, if an undesirable, place in the market. Before passing on to consider the extent of its admixture with other cottons in Gujarat at present, we may notice the theories which can be put forward to account for its existence. The first theory on the subject is that of Middleton (*loc. cit.*) who considered that it is probably a cross between the *Broach deshi* cotton and the *Wagad* cotton of Northern Gujarat. The ground for this opinion is based on the fact that *Broach deshi* cotton boils open wide and completely: those of *Wagad* only open slightly and have to be broken open to extract the cotton. In the case of *Goghari* various degrees of opening occur, some strains being almost as closed as *Wagad* when ripe, while others are intermediate between the two in this character. Against this opinion it may be noted, however, that the *Goghari* lint is whiter than either of its supposed parents, and, further, the ginning percentage is higher than either of *Wagad* or *Broach deshi*. These seem to make it at least doubtful, and it is, perhaps, more probable that *Goghari* really represents a developed and acclimatized *Wagad* type of cotton than a cross of the nature above indicated. In studying the various strains contained in *Wagad* cotton, we have, in fact, been able to isolate strains which are very similar to *Goghari* in manner of growth as well as in boll characters.

3. *Extent of admixture of* Goghari *with other cottons in Gujarat.*

On the strength of its high ginning percentage there has been a gradual tendency for *Goghari* cotton to spread throughout Gujarat until it is now found in almost every part of the province. Its ginning percentage is, however, its only advantage. The yield of *kapas* is certainly not greater than with other types of cotton equally suitable for almost every corner of the country, and the staple is recognized by all concerned to be inferior to that of the cottons which were formerly grown exclusively in these areas. But the difference in price resulting from the higher staple has not during the last twenty years been sufficient to prevent the temptation of a higher yield of lint on the *kapas* obtained leading to the gradual penetration of *Goghari* cotton throughout Gujarat.

In the year 1905, and again from 1909 to 1919, a number of samples of seed has been collected from ginning factories in many parts of Gujarat, and have been, after sowing and reaping of the crop obtained, used to determine the extent to which *Goghari* cotton was actually being grown in the various tracts. In the early years the samples were collected by the Mamlatdars or revenue sub-divisional officers; since 1913–14, the officers of the agricultural department have been responsible for obtaining them. The results of the examination of these samples can now be indicated.

Surat District. The reliable samples of seeds collected in the early years were too few to be of any value for the purpose in view, but since 1912-13 the following table indicates the amount of *Goghari* cotton contained in the samples of seed collected :—

Year	Number of samples examined	Average percentage of *Goghari*
1912–13	8	1·3
1913–14	15	1·0
1914–15	17	0·2
1915–16	30	0·6
1916–17	26	3·7
1917–18	18	0·9
1918–19	11	7·5

These figures, which owing to the limited number of samples examined must only be approximate, indicate that until recently the penetration of *Goghari* cotton into the Surat District has been only small. In 1916–17 for the first time it amounted on an average to nearly four per cent. and though in 1917-18 the figure obtained went down, it rose to an unprecedented height in 1918–19. The chief disquieting feature in the last year was the fact that all samples showed a mixture, and hence it was clear that *Goghari* cotton seed was penetrating everywhere, even in the areas where the highest staple strains of *Broach deshi* cotton had been previously grown. The result has been that the trade has become alarmed, and that an effort against the further invasion of *Goghari* types is being made by the combined action of the agricultural department in supplying pure seed, and of the various sections of the trade.

Broach District. The examination of samples from the Broach District has been more satisfactory and has given clear results showing the penetration of *Goghari* cotton. Here it must be remembered, we are in the centre of distribution, and though in 1905 the pure *Goghari* cotton

was confined to one corner of the district, yet the ease with which it could be spread led to its rapid extension. The actual averages obtained were as under :—

Year	Number of samples examined	Average percentage of *Goghari*
1914–15	18	22·3
1915–16	19	24·2
1916–17	18	40·6
1917–18	24	50·7
1918–19	13	81·8

From these figures it is clear to what extent *Goghari* cotton has replaced the older type of *Broach deshi* of superior staple. This is partly due to the mixture of seed : partly to the actual replacement of the one variety by the other. In 1918–19, in almost a quarter of the cases the samples received were almost pure *Goghari* cotton seed, in the remainder the admixture varied from 65 to 88 per cent. of *Goghari* seed. There was no pure *Broach deshi* seed sample among them.

The same penetration of *Goghari* seed from Broach into Ahmedabad and Kaira is taking place as is occurring in Surat, but already it has proceeded much further. Viramgam and the surroundng tracts are little affected as yet but everywhere else the *Goghari* type is becoming increasingly grown from year to year The number of samples examined is, however, not sufficient to justify a quotation of them, but there is no doubt that the spread is taking place, a spread which is tending to ruin the reputation of Gujarat as an area for producing a staple cotton.

4. *Has hybridization occurred among the various types of Gujarat* herbaceum *cottons ?*

With regard to the various types—*Wagad, Broach deshi* and *Goghari*—of Gujarat *herbaceum* cottons, which are growing together or in close proximity in so many parts of the province, two things may have occurred. Either they are growing side by side without appreciable mixture, or they have largely hybridized and so every form of cross intermediate between the types will be found. If the former be the case, then it will be easy to obtain each variety pure by simply selecting plants true to any type in the field : if, on the other hand, the latter be the condition, it will be difficult by field selection directly to get plants which will breed true of any of the varieties described.

The extent to which hybridization of cotton takes place generally has been a matter of considerable controversy. Without going into the older literature on the subject, we may call attention to Gammie's opinion in 1903.[1] He states as follows :—

" It is customary among botanists to assume that the numerous forms of cotton plants have become inextricably complicated and difficult to understand and distinguish through hybridization. It appears to the writer that the true solution of the problem of classification will be found to lie in the fact that, in the Indian form, these so-called species and hybrids are merely cultivated races evolved from an unknown prototype." A little later (1905) Gammie[2] was more definite, and stated that in his opinion the numerous forms occurring in every species of Indian cottons were not to be explained through hybridization, in that Indian cottons are normally self-fertilized. " A large number of varieties," he said, " procured from almost every part of the country have been grown in contiguous lines without hybridizing. Emasculated flowers allowed to remain uncovered usually drop off unfertilized. In the few cases where pollen was carried to the stigmas by insects, bolls were not subsequently developed."

This very clear opinion that crossing among Indian cottons is of rare occurrence, and, when it occurs, is of little practical importance, is not shared by other workers on the subject. Watt[3] writes as though he considered that cross-fertilization was frequent and that many Indian types have risen through such natural hybridization. Leake[4] after a very careful series of observations came to the conclusion that in Indian cottons " cross-fertilization takes place to a considerable extent, though the greater portion of this is limited to neighbouring plants." He says, further, that cottons which flower by the end of the rainy season are more liable to cross-fertilization than others.

It may well be, however, that in different species of cotton, the tendency towards hybridization will be very different. Thus, for instance, cross-fertilization would be very difficult in *Gossypium arboreum* with its short style, while in the various types of *Gossypium neglectum*, where the length of style gives much more opportunity for foreign pollen to be received, it might easily be frequent. The forms of *Gossypium herbaceum* occupy an intermediate position, and none of the workers above quoted have made careful and detailed observations of the incidence of crossing with this species.

[1] Note on the Classification of Indian Cottons, Calcutta, 1903.
[2] The Indian Cottons, Calcutta, 1905.
[3] Wild and Cultivated Plants of the World, London, 1907.
[4] *Mem. Dept. Agri. India, Botanical Series*, IV, no. 3.

We have, however, now the recent work of Kottur[1] on this point. He worked with various types chiefly of *herbaceum* cottons, and concluded that "all the Indian varieties cross easily and the amount of natural crossing is considerable (up to 6 per cent.) when various varieties are grown in adjoining fields." Beyond this opinion there is no evidence, so far as we are aware, of the degree to which cross-fertilization occurs among *herbaceum* cottons, or of the extent to which the plants now grown are unfixed hybrids of the various varieties in cultivation.

That cross-fertilization does actually occur in the *Goghari* type of *herbaceum* cotton is clear from the following experiment:—

Strain No. C 8 *Goghari.* This is a pure line cultivated without variation for several seasons. In 1918–19 the seeds produced by two separate plants of 1917-18 were sown, and variations in the amount of *kapas* per boll and in the ginning percentage of the *kapas* were noted which could only have resulted from crossing. The rows were planted at least six feet from any other type. The actual figures obtained were as under:—

Number of bolls per pound of *kapas*	No. 1–348 No. 2–407
Ginning percentage	No. 1–44·2 No. 2–46·6

Degree to which cross-fertilization occurs. We have started our work by isolating pure line cultures of *Goghari* cotton which have maintained certain of their characters for at least two generations. The seeds produced in open field cultures in the second generation (the plants being grown no less than six feet by three feet apart) have then been grown, and the proportion of the plants which have varied in the next generation in the character studied has been determined. The only source from which such variations could arise was cross-fertilization from the plants in the field. The following cases may be quoted:—

1. *Strain No.* B21 *Goghari.* The character studied was the size and shape of the boll. This was absolutely constant in 19–1617 and 1917–18. On being grown in open culture in 1918–19, it showed 2·1 per cent. of the plants bearing bolls of a different character. Again a plant bearing bolls of the original shape and size in 1918–19 gave 2·85 per cent. of the plants with varying bolls in 1919–20.

2. *Strain No.* C22 *Goghari.* The same character was studied as in the last case, and the boll characters of the strain were constant in 1917–18 and 1918–19. In 1919–20 this showed plants with varying bolls to the extent of 1·1 per cent.

[1] *Mem. Dept. Agri. India, Botanical Series,* X, no. 6, 1920.

3. *Strain No.* B3 *Goghari.* The boll characters were again studied and after being constant in 1916-17 and 1917-18 these showed 1 per cent. of the plants in 1919–20 with varying bolls.

Judged therefore by this one character, it would suggest that under the conditions of the experiment, in which the nearest differing plants of other strains would be six feet or more away, the amount of crossing would, in *Goghari* cottons be between 1·0 and 2·8 per cent.

That the plants at present grown are unfixed hybrids of the varieties in cultivation is still more clear. Seed of two types of *Goghari* cotton (Jambusar *Goghari* and Varnama *Goghari*) were obtained and sown. From the crop obtained, all plants were eliminated which showed any character other than those associated with *Goghari* cotton. Seed was produced from the remainder and this was again sown. Instead of producing pure *Gohgari* plants, however, the latter showed a higher percentage of admixture with those of other types than did the original cotton. The actual figures in both cases are as under :

Year	Jambusar *Goghari* Percentage of admixture of *Broach deshi*	Varnama *Goghari* Percentage of admixture of *Broach deshi*
First year (1913–14)	7·25	9·50
Second year (1914–15)	14·00	10·00

It is clear, therefore, that the plants grown were "splitting" as to one or more of the characters associated with *Goghari* cotton.

A similar test was made with a sample of cotton seed, reputed to be *Broach deshi*, obtained at Broach. The seed was grown as before, and all the plants which did not conform to the *Broach deshi* type were eliminated, and the seed produced from the remainder was sown in the following generation. In this case the series was continued for four years ; only in the fourth year had the *Goghari* type been entirely got rid of, as the following figures show :—

	Broach deshi Percentage of of admixture with other types
First year (1913–14)	82·3
Second year (1914–15)	14·8
Third year (1915–16)	2·5
Fourth year (1916–17)	0·0

A third test may be quoted. In seeking to develop pure strains of *Goghari* cotton, we commenced by selecting in the field, with great care, plants which completely conformed to the *Goghari* type. The seeds from these plants were sown, and the plants from their produce were examined. The following table shows the percentage of these which conformed to the *Goghari* type in 1915–16 :—

Strain	per cent.
A ..	.. 43·9
B ..	.. 40·3
C ..	.. 45·1

Allowing that a limited amount (not more than 3 per cent.) of cross-fertilization may have taken place in the field, this would be totally insufficient to account for such a large proportion of non-*Goghari* plants in the offspring of those selected.

These results, therefore, seem to show conclusively in the *herbaceum* cottons of Gujarat, or at any rate in the *Broach deshi* and *Goghari* types, the following points :—

(1) That cross-fertilization of the different types of *herbaceum* cottons does take place.

(2) That this cross-fertilization takes place normally to the extent of 1 to 2·85 per cent. and perhaps more.

(3) That the cotton plants in cultivation are very largely composed of hybrids between the various types described, and, hence, ordinary selection on the basis of the characters of the produce of a particular plant will not yield a constant type either of plant or produce.

5. *What characters are hereditary in* Goghari *cotton ?*

In considering which of the characters associated with *Goghari* cotton are hereditary, we have studied the following. We will first state what we have found with regard to each of them and then describe the data on which these conclusions are based.

Boll characters.

(1) The shape of the boll (spherical, tapering, etc.) is hereditary.

(2) The size of the boll, at any rate so far as the spherical type of boll is concerned, is hereditary.

(3) The quantity of *kapas* per boll is hereditary.

Plant Characters.

(1) The proportion of bolls borne on primary fruiting branches is hereditary.

Seed and lint characters.

(1) The ginning percentage of the *kapas* is hereditary, but there are variations from season to season due to reasons other than seed weight.

(2) The seed weight is hereditary.

The evidence on which these statements are based is as follows :—

1. *The shape of the boll is hereditary.*[1] In ordinary *Goghari* cotton, as grown, there are very great variations in the type of boll. Some of these variations are shown in Plate V, fig. 2, which represents the character of the bolls in a number of strains (pure) which we have isolated and each of which is described in the next section of the present paper. These may be indicated as under :—

A. Spherical in shape and large.
B. (1) Long and tapering with smooth surface.
   (2) Tapering with rough surface.
C. Spherical, but small.
E. Intermediate in type between A and B.

The original types, from which these strains have been developed, were selected in 1914–15, on the basis of these very boll characters. On growing, however, they were found each to yield plants with bolls of the most varying kinds, more than 55 per cent. in the case of types A, B, and C being rejected in the first year's crop. By careful selection, however, plants have been obtained which breed entirely true to this character. In the strains with boll characters represented by A, plants had been evolved by 1918–19 whose progeny gave an absolutely uniform series of spherical bolls, breeding true year after year. Similarly in strains with the characters of B and C, the same stage was reached in 1916–17, while in those with characters of E, the plants bred true as to the type of boll in 1917–18.

2. *The size of the boll and the quantity of* kapas *per boll are hereditary.* In an ordinary collection of bolls of *Goghari* cotton the variation in size is very great, even in the same season. Some idea of this can be given by figures for a large number of bolls from our own plots, which are of course more uniform than the types in ordinary fields. The size will perhaps be best indicated by the number of bolls required to give one pound of *kapas*. This varied in two different years as follows :

1917–18. 181 to 247 or a variation from the mean of 15·4 per cent.

[1] Balls. "The Cotton Plant in Egypt," London, 1912.

1918–19. 214 to 289 or a variation from the mean of 14·9 per cent.

Several strains have been isolated in which the number of bolls required to yield one pound of *kapas* is almost constant in any one season.

Thus the progeny of different plants of one pure line gave the following numbers in certain cases.

(1) 217 and 214 from a parent giving 220 bolls per pound of *kapas*.

(2) 186, 193, 208 and 210 bolls per pound of *kapas* (parent not recorded).

(3) 249 and 241 from a parent giving 241 bolls per pound of *kapas*.

(4) 273 and 288 bolls per pound of *kapas*.

In these cases the variation from the mean among the progeny is only 0·7, 6·5, 1·6 and 2·6 per cent. respectively, and in the cases where the character of the parent was recorded, the variation is 2·8 and 3·3 per cent., though the parent and the progeny were grown in different seasons.

3. *The proportion of bolls borne on primary fruiting branches is hereditary.* It is well known that in all *herbaceum* cottons there are three positions in the plant in which bolls may be borne. They may arise on secondary or tertiary branches, borne either on monopodia near the base or on vegetative axillary shoots growing in the upper part of the plant ; and they may occur on primary fruiting branches arising directly from the main stem. In most species of cotton, the last kind of bearing is almost exclusively found : in *herbaceum* cottons, the former kind has a very important share in the number of bolls and hence in the quantity of *kapas* produced. The proportion of the total number of bolls borne on the primary fruiting branches seems, however, to be constant for a pure strain in *Goghari* cotton.

The following table gives figures showing how the progeny of selected plants of each strain are constant in this factor.

Table showing percentage of bolls borne on primary fruiting branches.

		Percentage	
	Strain A26	1918–19	1919–20
Progeny of plant 1	.. ..	30·6	..
Progeny of plant 2	.. ..	30·3	..
	Strain B3		
Progeny of plant 1	.. ..	36·8	
Progeny of plant 2	.. ..	35·0	..
	Strain B21		
Progeny of plant 1	.. ..	21·6	..
Progeny of plant 2	.. ..	22·5	..
	Strain C22		
Progeny of plant 1	.. ..	33·3	..
Progeny of plant 2	.. ..	29·0	..
Progeny of plant 3	.. ..	29·0	..
Progeny of plant 4	.. ..	28·8	..

Strain E5	Percentage 1918–19	1919–20
Progeny of plant 1	32·5	32·4
Progeny of plant 2	36·0	33·8

The variation between the progeny of different plants is so small, and, moreover, the difference in the last quoted case is so slight from year to year, that it justifies us in concluding that we are here dealing with a hereditary factor. This matter, however, requires further study.

4. *The ginning percentage of* kapas *is hereditary.* Seeing that in *Goghari* cotton it is the high ginning percentage which has raised the variety to its present importance, it is a matter of great interest to ascertain how far this quality is one which is innate in any particular strain, and hence whether strains can be isolated which possess this very valuable character in an exceptional degree, and which will breed true. Our observations show that such strains can be isolated, that plants derived from similarly bred parents in pure line will have similar ginning percentage, and that the ginning percentage of the progeny, in pure strains, will only vary within defined limits from that of the parents.

We will give the figures obtained for the ginning percentage in several pure strains and for a series of years.

		Ginning percentage
Strain A26	1916–17	44·6
	1917–18	42·7
	1918–19	45·7, 45·4 and 46·6
	1919–20	42·5
Strain B3	1916–17	42·6
	1917–18	42·7, 42·8, 42·5, and 43·8
	1918–19	45·8 and 45·1
	1919–20	46·9
Strain B21	1916–17	45·4
	1917–18	42·6
	1918–19	45·5 and 44·6
	1919–20	44·8
Strain C22	1916–17	46·1
	1917–18	42·0, 42·5, 42·4 and 42·9
	1918–19	45·7 and 45·8
	1919–20	47·6
Strain E5	1916–17	46·4
	1917–18	46·7, 46·1 and 46·6
	1918–19	49·8 and 48·8
	1919–20	51·5

The variation between the progeny of different plants of the same strain grown in the same year is very small indeed. Environmental factors appear to have a very large effect on the ginning percentage in any one year

as compared with any others, and they seem, moreover, to have a somewhat different effect in different strains (*e.g.*, A26 and B3). But there are strains which consistently give a very high ginning percentage like E5, and which may have great importance from a breeding point of view on this account.

A critical examination of these figures, however, suggests that the ginning percentage is itself a complex, being dependent on the weight both of the seeds and of the lint. A rise in the ginning percentage might in fact be brought about either by an increase in the lint weight or by a decrease in the seed weight, and hence a better figure to measure the proportion of lint in a well-developed boll would be to compare the weight of lint with the number of seeds and not with their weight. That is to say, we should use a figure which compares the weight of lint per 100 seeds. This figure has been already used by the writers in Egypt under the name " Lint-index " and its value in the cases quoted in the last table is as follows :—

Lint-index (weight of lint in grammes per 100 *seeds*).

		Grm.
Strain A26	1916–17	4·31
	1917–18	4·29
	1918–19	4·80, 4·91 and 5·04
	1919–20	4·82
Strain B3	1916–17	4·11
	1917–18	4·04, 4·13, 4·05 and 4·25
	1918–19	4·66 and 5·05
	1919–20	5·15
Strain B21	1916–17	4·01
	1917–18	3·98
	1918–19	4·30 and 4·30
	1919–20	4·60
Strain C22	1916–17	4·33
	1917–18	3·73, 3·93, 3·92 and 3·95
	1918–19	4·29 and 4·37
	1919–20	4·80
Strain E5	1916–17	4·49
	1917–18	4·75, 4·69 and 4·84
	1918–19	5·50 and 4·96
	1919–20	5·73

The constancy of the lint-index is greater than that of the ginning percentage as is well illustrated in the case of Strain A26, 1919–20, as against 1918–19, and hence it appears to be a better factor to use in considering the relationship of the lint and the seed.

It is a general belief among cotton merchants that variation in the ginning percentage in one type of cotton is due simply to variation in the seed weight. Our results show, however, that this is not the case, and that in any of our pure strains the variation in the seed weight is only one of the factors

which causes changes in the ginning percentage. The following table shows the ginning percentage in several years, and also the number of seeds per gramme. There is obviously little or no correlation between the two sets of figures.

Strain	1916–17		1917–18		1918–19		1919–20	
	Ginning percentage	Seeds per gramme	Ginning percentage	Seeds per gramme	Ginning percentage	Seeds per gramme	Ginning per centage	Seeds per gramme
A26	44·6	18·6	42·7	17·3	45·9	17·2	42·5	15·3
B3	42·6	18·0	42·9	18·3	45·4	17·2	46·9	17·2
E5	46·4	19·3	46·5	18·4	49·3	18·5	51·5	18·5

5. *The seed weight is hereditary.* This has already been recognized by Balls[1] for Egyptian cotton, and it is equally the case in the *Goghari* variety of *Gossypium herbaceum*. The following figures for the same strains which we have considered under the last heading make this clear in the present case :-

		Number of seeds per 10 grm.
Strain A26 ..	1916–17 ..	186
	1917–18	173
	1918–19	175, 169 and 173
	1919–20	153
Strain B3 ..	1916–17 ..	180
	1917–18	184, 181, 182 and 183
	1918–19	179 and 163
	1919–20	171
Strain B21 ..	1916–17 ..	207
	1917–18	186
	1918–19	194 and 186
	1919–20	176
Strain C22 ..	1916–17 ..	196
	1917–18	194, 188, 187 and 190
	1918–19	196 and 193
	1919–20	189
Strain E5 ..	1916–17 ..	193
	1917–18	184, 185 and 180
	1918–19	180 and 192
	1919–20	185

These figures indicate that the progeny of different plants of the same strain grown in the same year give seed whose weight varies very slightly. It also shows that despite considerable variations from year to year,

[1] Balls. "The Cotton Plant in Egypt," London, 1912, page 167.

a heavy-seeded variety remains relatively heavy-seeded however the environmental factors may vary.

Closely connected with this study of some of the characters of *Goghari* cotton which we have proved to be hereditary, we may note the results of our inquiry into the correlation between the shape and size of the bolls in *Goghari* cotton and the ginning percentage. In commencing selection work on this cotton in 1914–15, we relied on this character of the bolls as being a favourable basis for selection as a result of statements by several authorities that boll characters were intimately associated with length of fibre. Thus O. F. Cook[1] states definitely that there is a correlation between the length of the boll and the length of the fibre. Kearney[2] also, in his study of breeding in Egyptian cotton, ventures the statement that " the size of the bolls must be considered, ...because this character is intimately associated with length of fibre." He does not give any evidence for this, and we cannot find the evidence on which it was based. Main[3] held the same opinion, and stated that in 1911–12 he made the " interesting observation that a correlation exists in the indigenous cottons between the ginning percentage on the one hand and the shape of the bolls on the other." A broad-shaped boll was found to be associated with a higher ginning percentage in the *kapas*. He, however, does not give the evidence on which he based this statement.

After six years' work on the subject we have to say that we have failed to find the correlation expected ; although all our selections were originally made on the basis of the size and shape of the bolls, yet the pure strains we have developed from them have not given a ginning percentage which varies in any sense according to their origin. The following table shows this :—

Strain	Boll characters	Ginning percentage			
		1916–17	1917–18	1918–19	1919–20
A26	Spherical and large	44·6	42·7	45·9	42·5
B3	Tapering and large	42·6	42·9	45·4	46·9
B21	Tapering and medium size	45·4	42·6	45·5	44·8
C22	Spherical and small	46·1	42·5	45·7	47·6

[1] *Bulletin* 159, *U. S. Dept. Agri. Bur. Plant Industry*, p. 45.
[2] *Bulletin* 200, *U. S. Dept. Agri. Bur. Plant Industry*, 1910, p. 11.
[3] *Annual Report Surat Experimental Station*, 1911-12 (Bombay, 1912).

The supposed connection between the shape and size of the bolls obviously does not exist. The highest ginning percentage in the series has been given by a plant with small bolls which were spherical, and the lowest by one which had large and spherical bolls.

Another correlation which has been announced to occur is that between the size of seed and yield which plants produced from it might be expected to give. This was stated by Cook[1] in 1908, where he describes the advantages of light seeds, heavy seeds and large-seeded varieties. On the strength of experiments by Shoemaker on " Triumph " cotton, he connected the increase in yield rather with the development of large seeds. That there is no necessary connection between heaviness in seed and the yield of a variety in *Goghari* cotton is indicated by the following table. A26 was a heavy-seeded strain ; C22 on the other hand was a light-seeded strain, the seeds being 5 per cent., 7·8 per cent., 10 per cent. and 19 per cent. lighter than those of A26 in the four years 1916–17, 1917–18, 1918–19 and 1919–20 respectively. The table indicates the yield per plant in these four years.

Yield of kapas *per plant.*

Strain	1916–17 Grammes	1917–18 Grammes	1918–19 Grammes	1919–20 Grammes
A26 (heavy-seeded)	2·90	7·87	5·38	7·91
C22 (light-seeded)	4·44	4·94	6·30	7·88

The yield and weight of seed, therefore, seem to depend on altogether different factors, and no connection seems to exist between them whatsoever.

One more point in correlation arises. It has been suggested by Gammie[2], though he gives no evidence whatever in favour of his assertion, that a tall shortly branched form of the cotton plant "appears to be the more productive in all species of Indian cottons." A statement which might be interpreted to mean the same was issued by Kottur[3] in 1917, but he has since made it clear that the tallness of the plant has, in his opinion, nothing to do with the yield, but rather the proportion between the different types of branches (fruiting) on the plants. In view of Gammie's statement, however, it was necessary to ascertain whether there was any connection between tallness and yield, as

[1] *U. S. Dept. Agr. Bur. Plant Industry, Circular* 11, 1908.
[2] *Report of the Imperial Cotton Specialist*, 1916–17, p. 3.
[3] *Bulletin no.* 84, *Dept. of Agri. Bombay*, 1917.

we have again and again, as a result of it, been recommended to carry on selection on the basis of the tallness of the plants used for the purpose. We have separated two strains : one (B3) which was the tallest of all in the sense that the main stem tended to develop to a great extent, and the other (E 5) which did not have this faculty. The yield in *kapas* of each of these strains per acre grown side by side, in a series of years, was as follows :—

Year	B3 (Tall strain)	E5 (Strain not tall)
	lb.	lb.
1917–18	157	164
1918–19	253	318
1919–20	332	510

It is obvious that in these two strains, both isolated from *Goghari*, there is no correlation between tallness and yield. It is difficult to understand how anyone ever supposed that such correlation was likely to exist.

6. *Description of certain pure line strains of* Goghari *cotton.*

From the discussion of *Goghari* cotton so far made, it has become clear that what goes under that name really consists of a series of strains, all of which possess the varietal features described on page 83, but which differ from one another by characters which are very important commercially, and of which some, at least, are hereditary and breed true. These strains, however, are not merely mixed ; they have crossed with one another to an enormous extent, and few, if any, of a pure character now exist in the whole province. Any attempt to improve or even to fix a standard type for *Goghari* cotton must be commenced, evidently, by the development of such pure strains breeding true, which could be the basis of establishing types or of making crosses with other strains of *Goghari* or with other varieties of cotton.

We have isolated five strains of *Goghari* cotton, and we may now give a description of each of these as it has behaved in pure line culture since 1916–17 or 1917–18.

Strain A26.

The first of these selected strains, which has been termed A26, is derived from a selection originally made on the basis of the shape and the size of the boll. The manner of making the selection, in the first instance, was to pick out

in an ordinary field of *Goghari* cotton, 188 plants which had round, spherical and large bolls. The progeny of each of these plants was sown separately in a row, the rows being six feet apart : from the resulting plants all of which did not produce the same characters in the bolls for which they had been selected were eliminated leaving those which still gave the characters desired. Since that time unit selection among the plants so left has been carried on, with the result that since 1918–19 we have a type which has bred absolutely true, and which represents a pure line with the following characters.

The plant of the strain is of a bushy character, and bears a number of monopodia varying from one to eight, the most frequent being four to five. The leaves and formation of the plant are similar to what is usually found in *Goghari* plants. The special characteristics are :—

(1) The bolls are spherical and large, with a very marked point at the tip. The bolls open well on the plant, and are fairly uniform in character. The average weight of *kapas* per boll is 2·12 grm.

(2) The *kapas* gave a ginning percentage of 45·9 in 1918–19 and 42·5 in 1919–20. The lint-index (that is to say, the weight of lint in grammes per 100 seeds) was 4·93 in 1918–19 and 4·82 in 1919–20.

(3) The seed is rather larger than the average for *Goghari* cotton, and 100 seeds weighed in 1918–19, 5·81 grammes. In 1919–20, 100 seeds weighed 6·53 grammes.

(4) The lint varies in length of staple according to the part of the seed from which it is derived. In 1920 the average length was as follows : —

	Centimetres
Lint on tip of seed	1·72
Lint on middle of seed	2·01
Lint at base of seed	1·91

The variation in the length of the staple of the lint at the various parts of the seed is : (1) at the tip 8·5 per cent. below the mean ; (2) at the middle 7 per cent. above the mean ; (3) at the base 1·6 per cent. above the mean. The attached frequency curve shows the extent to which the staple of the lint from the middle of the seed varies in a lot of seed of the pure strain.

The comparative constancy of the staple is shown by the following figures, all taken in the middle of the seed.

Number of measurements made	.. .. ..		100
Staple of 1·7 centimetres	.. .. ..		1
Do. 1·8	Do.		17
Do. 1·9	Do.		11
Do. 2·0	Do.		28
Do. 2·1	Do.		20
Do. 2·2	Do.		13
Do. 2·3	Do.		7

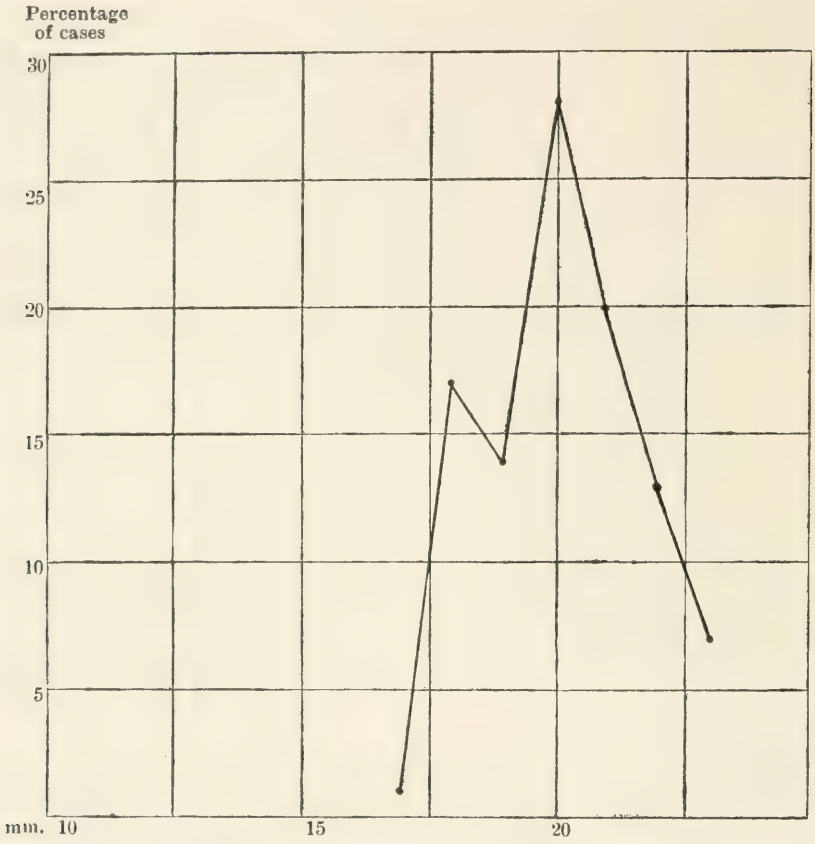


FIG. 2. Variation in length of staple on the middle of the seed in *Goghari* A26.

The lint from this strain of *Goghari* cotton has been very kindly examined by Messrs. Tata & Sons, Bombay, both in 1918–19 and 1919–20. The following are their valuations :—

Year	Value of lint per *candy* of 784 lb.	
	Fine Broach deshi	A26
	Rs.	Rs.
1918–19	600	450
1919–20	500	300

Such are the characters of this, the strain which perhaps most nearly approaches the typical *Goghari* cotton as grown in the country. It is retained

Right side. Goghari B 3, having a tall habit of growth. Where the plants are pruned off, even the axillary vegetative branches have grown tall.

Left side. Goghari E, having no such tall habit.

PLATE VI.

in our collection not on account of superiority of either staple or ginning percentage but because it is an all-round good yielding cotton. Its ginning percentage is slightly above the average, while the staple represents about the mean for *Goghari* cotton.

Strain B3.

In the same year as the strain previously described was first selected, plants were picked out which had large and tapering bolls, for it was supposed at that time that a large boll means a cotton with a high ginning percentage and a tapering one would be likely to give a higher staple lint; unit selection was continued on the same basis in succeeding years, and a pure strain with the above boll characters breeding true was obtained in 1916–17. It was then discovered that the strain obtained had another character, namely, that the main stem was inclined to develop to an exceptional extent, and hence to give a tall habit to the plants.

We have, hence, a plant which while giving about the same number of monopodia as the strain previously described (the most frequent number being 5) and which hence is bushy in character, at the same time grows tall. The habit of the plant is well shown in Plate VI when it is compared with a strain (E5) later to be described. The tall character is so far a special feature of the strain that if the main stem is pruned, the axillary vegetative branches grow vertically and still give a plant a tall appearance. In other respects the plant is typical *Goghari* in character.

The flowering of this strain of cotton was observed in 1918-19, when the succession of flowers in twelve plants was noted as follows :

Number of flowers	from October	11 to 17 ..	142
Do.	Do.	18 to 24 ..	145
Do.	Do.	25 to 31 ..	193
Do.	from November	5 to 10 ..	148

A gap occurred between October 31st and November 5th, but these figures nevertheless show that the flowering is steady for over four weeks, rising to the greatest frequency in the latter part of the period. After the date above given rain occurred and flowering stopped.

The special characters of the produce in the strain of cotton are as follows :—

(1) The bolls are tapering, studded with dark dots on the surface which is rough. The bolls open as in a typical *Goghari* plant ; the weight of *kapas* per boll was :—

	Grm.
(*a*) in 1917–18 ..	2·27
(*b*) in 1918–19 ..	1·70

(2) The *kapas* gave a ginning percentage and lint-index as follows :-

Year	Ginning percentage	Lint-index
1916–17	42·6	4·06
1917–18	42·9	4·11
1918–19	45·4	4·85
1919–20	46·9	5·15

These figures show a tendency, under the conditions of the last two years, for both the ginning percentage and the lint-index to increase.

(3) The seed was about the average size and 100 seeds weighed as follows : —

Year	Weight of 100 seeds grm.
1916–17	5·55
1917–18	5·47
1918–19	5·85
1919–20	5·84

(4) The lint gave the following average measurements on the different parts of the seeds in 1920 :—

	Centimetres
Lint on tip of seed	1·63
Lint on middle of seed ..	1·94
Lint on base of seed	1·74

The variation from the mean (*a*) at the tip was 7·9 per cent. below, (*b*) at the middle 9·6 per cent. above, and (*c*) at the base 1·7 per cent. below.

The lint on the middle of the seed varied as follows, as determined from 100 measurements made on seeds :—

Number of measurements made ..	..	..	00
Staple of 1·5 centimetres	..	..	1
Do. 1·6 Do.	..	..	10
Do. 1·7 Do.	..	..	6
Do. 1·8 Do.	..	..	8
Do. 1·9 Do.	..	..	22
Do. 2·0 Do.	..	..	20
Do. 2·1 Do.	..	..	22
Do. 2·2 Do.	..	..	10
Do. 2·3 Do.	..	..	1

The staple in this case is, therefore, not only shorter than with A26, but is also more uneven. The variation is illustrated in Fig. 3 below.

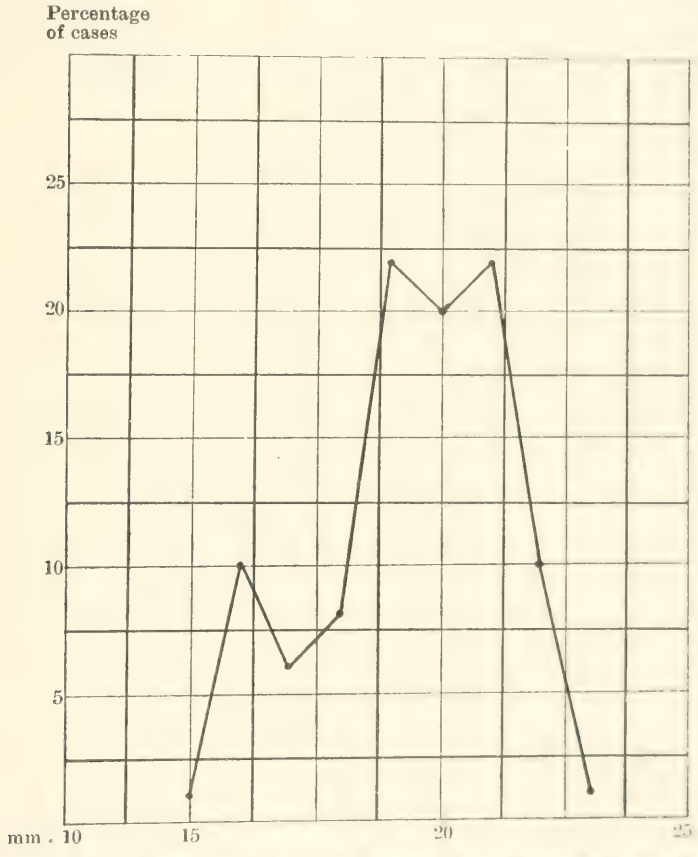


Fig. 3. Variation in length of staple on the middle of the seed in *Goghari* B3.

The lint was examined by Messrs. Tata & Sons, Bombay, in each of the years when it was grown, with the following results :—

Year	Value of lint per *candy* of 784 lb.		
	Fine Broach deshi.	B3	A26
	Rs.	Rs.	Rs.
1916–17	500	418	..
1917–18	950	800	..
1918–19	600	520	450

The strain just described possesses few characters which give it value. It is a low yielder, and its lint is not only short but is also uneven as in other strains of *Goghari* cotton. It is maintained simply because of its tall habit of growth, which may later cause it to be useful for crossing. As it stands, it is only valuable as showing the low characters of certain of the pure strains in *Goghari* cotton.

Strain B21.

All the strains of *Goghari* separated originally in 1914–15 and marked B were selected because of their tapering bolls, whic hwere supposed (as already remarked) to be connected with long staple in the lint. In the present case the boll was, however, only me lium size. It was considered as promising in the following year, and was obtained pure in 1916–17 so far as the boll characters are concerned. The strain has turned out to be of a very leafy character. The plants are not only leafy, but give more monopodia than the strains hitherto described. The most frequent number of thise typ of branch is six, and hence it is more bushy. As a result apparently of this, the percentage of bolls borne on the primary fruiting branches is less than in any other of our pure strains (page 94).

The special characters of the produce of this strain are as follows :—

(1) The bolls are medium in size, and distinctly tapering. They open more widely than in any strain that we have isolated, but the valves do not recurve. The average weight of *kapas* per boll was :—

	Grm.
(*a*) in 1916–17	1·73
(*b*) in 1917–18	1·88
(*c*) in 1918–19	1·84

(2) The *kapas* gave a ginning percentage and lint-index as follows :–

Year	Ginning percentage	Lint-index
1916–17	45·4	4·01
1917–18	42·6	3·98
1918–19	45·0	4·30
1919–20	44·8	4·60

It will be noticed in 1919–20 that although the ginning percentage has gone down, the lint-index has gone up.

(3) The seed was of average size and 100 seeds weighed as follows :—

	Weight of 100 seed
	Grms.
1916–17	4·83
1917–18	5·36
1918–19	5·27
1919–20	5·67

(4) The lint gave the following average measurements on different parts of the seed in 1920 :—

	Centimetres
Lint on tip of seed	1·65
Lint on middle of seed	1·96
Lint on base of seed	1·82

The variation from the mean (*a*) at the tip was 8·8 per cent. below, (*b*) in the middle 8·2 per cent. above, and (*c*) at the base 0·5 per cent. above.

The lint on the middle of the seed varied as follows :—

Number of measurements made			100
Staple of 1·2 centimetres			1
Do.	1·3	Do.	0
Do.	1·4	Do.	0
Do.	1·5	Do.	1
Do.	1·6	Do.	2
Do.	1·7	Do.	4
Do.	1·8	Do.	18
Do.	1·9	Do.	23
Do.	2·0	Do.	20
Do.	2·1	Do.	15
Do.	2·2	Do.	10
Do.	2·3	Do.	6

The staple in this case is, therefore, shorter than in either A26 or B3 and is also very uneven even more so than B3. The variation is illustrated by Fig 4.

The lint, on examination by Messrs. Tata & Sons, Bombay, gave the following values :—

Year	Value of lint per candy of 784 lb.		
	Fine French desi	B21	A26
	Rs.	Rs.	Rs.
1916–17	500	460	..
1917–18	950	825	..
1918–19	600	450	450
1919–20	500	300	300

FIG. 4. Variation in length of staple in the middle of the seed in *Goghari* B21.

The strain so described is a very heavy yielder in an ordinary year, the best in fact among our strains, but in a year of drought it is much affected and the yield decreases more in proportion than with the strain E5. The bolls open well, which is also an advantage as this means ease of picking. These are its only advantages for with its low and very uneven staple—though it may be useful for crossing in order to get higher yield in a district of good rainfall—; it is, as it stands, a very low class of *Goghari* cotton.

Strain C22.

All our strains which have been marked as "C" were originally selected in 1914–15 on the basis of a small spherical boll. These were picked because Middleton (*loc . cit.*) suggests that under the name of *Gundi Goghari* types of cotton with small and round bolls gave cotton of quality higher than the

average. It was obtained pure so far as boll characters were concerned in 1917–18, and has bred true since then. Its chief character as a plant has turned out to be lack of leafiness. The plants, though not leafy, are bushy and give monopodia varying in number from two to nine ; the most frequent number of this type of branch is five, and in this matter it is similar to A26 previously described. The flowering was early as is shown by the following figures for flowers produced on twelve plants (*cf.* B3 previously given on page 103) in 1918–19.

Number of flowers	from October	11 to 17	.. 214
Do.	do.	18 to 24	.. 134
Do.	do.	25 to 31	.. 141
Do.	from November	5 to 10	.. 130

The flowering started earlier, but continued as late as other strains, so that its flowering period was longer. As a result of this, it yields the best in dry years, as the earlier formed flowers, which inevitably fall if rain occurs, are able to form bolls successfully.

The special characters of the produce in this strain of cotton are as follows :—

(1) The bolls are spherical and small, and the number on each plant is greater.– The opening of the bolls is poor, showing a tendency to be more of the *Wagad* type. The weight of the *kapas* per boll was :—

	Grm.
(*a*) in 1917–18	.. 1·78
(*b*) in 1918–19	.. 1·61

(2) The *kapas* gave a ginning percentage and lint-index as follows :

Year	Ginning percentage	Lint-index
1917–18	42·4	3·88
1918–19	45·7	4·33
1919–20	47·6	4·80

The figures show a tendency under the conditions of the last two years for both the ginning percentage and lint-index to increase.

(3) The seed was of smaller size than the types previously described, and 100 seeds weighed as under :

	Weight of 100 seeds
	Grm.
1917–18	5·27
1918–19	5·15
1919–20	5·20

(4) The lint gave the following average measurements on the different parts of the seed in 1919–20:—

	Centimetres
Lint on tip of seed ..	.. 1·59
Lint on middle of seed ..	.. 1·91
Lint on base of seed ..	.. 1·76

The variation from the mean (*a*) at the tip was 9·1 per cent. below, (*b*) at the middle 9·1 per cent. above, and (*c*) at the base 0·6 per cent. above. It was hence more uneven than the strains previously described.

The lint in the middle of the seed varied as follows, as determined from one hundred measurements made on seeds. It is shown in Fig. 5.

Number of measurements made			..	..	..	100
Staple of	1·5	centimetres	..	..	..	3
Do.	1·6	Do.	..	..	..	5
Do.	1·7	Do.	..	..	..	4
Do.	1·8	Do.	..	..	..	21
Do.	1·9	Do.	..	..	..	20
Do.	2·0	Do.	..	..	..	25
Do.	2·1	Do.	..	..	..	17
Do.	2·2	Do.	..	..	..	5

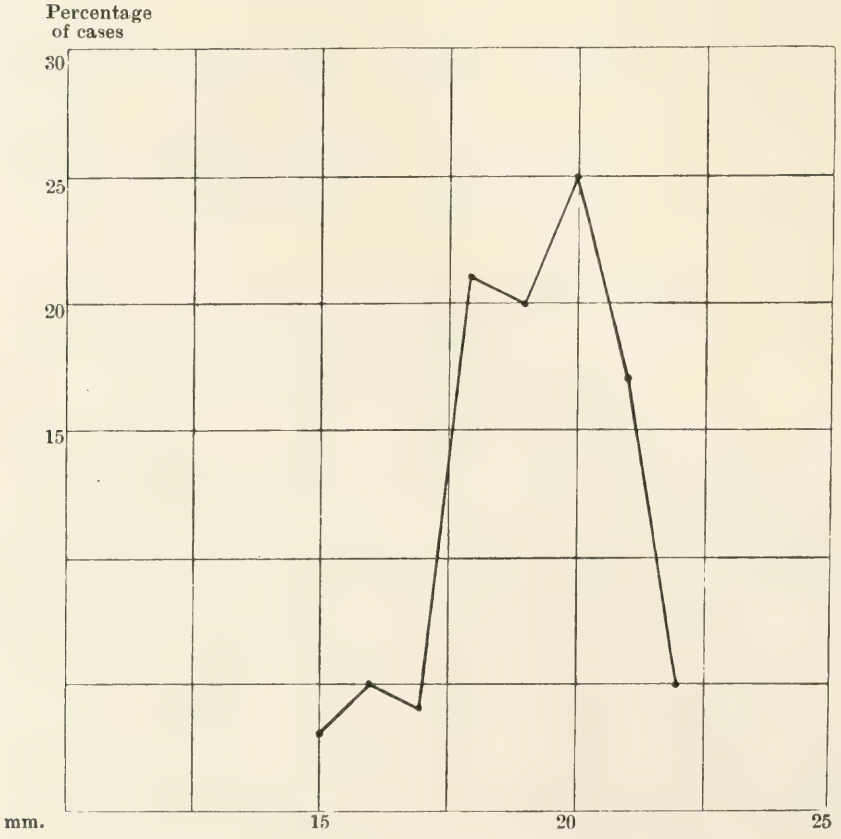


FIG. 5. Variation in length staple on the middle of the seed in *Goghari* C22.

The staple in this strain is shorter than in A26 and almost similar to B21. It is obvious that there is no necessary connection between the small boll and high quality cotton as was suggested by Middleton.

The lint on examination by Messrs. Tata & Sons, Bombay, gave the following values :—

Year	Value of lint per *candy* of 784 lb.		
	Fine Broach deshi	C22	A26
	Rs.	Rs.	Rs.
1917–18	950	775	..
1918–19	600	450	450
1919–20	500	280	300

On the whole, the strain may be described as a heavy yielder in dry years, the best, in fact, among our strains. In ordinary years it yields only moderately. Its ginning percentage is higher in fact than any except E5. These are its only advantages, for it has a low and very uneven staple. It might, however, be useful for crossing to get a higher yield and higher ginning percentage for the drier tracts. It is, as it stands, a very low class of *Goghari* cotton.

Strain E5.

This strain of *Goghari* cotton, whose ginning percentage is so high as to place it in a class by itself among *herbaceum* cottons, and which promises to be a very valuable discovery for purposes of crossing with strains of *Broach deshi* with better staple, was selected in 1914–15 from a plant bearing bolls intermediate in shape between the spherical 'A' and 'C' types and the tapering 'B'. It has been studied in greater detail than the other strain as its importance may be considerable in the future. It was obtained pure in 1917–18 and has been maintained so since that time, the boll characters breeding true in each generation.

The plants of this strain are of a less bushy character than those previously described. The number of monopodia varies from none to eight, the most frequent being three to four. This character appears to be constant from generation to generation. The rate of growth of monopodia indicates that it is a late type of cotton in an ordinary year, but that after three months these monopodia grow very rapidly indeed. This is on the whole an advantage as late growth and development of flowers are, in Lower Gujarat, an indication that there will be less shedding of flowers or bolls owing to rain. In the fourth

month the rate of growth of the main stem and of the monopodia was equal counted in nodes. The relative growth counted in nodes, at the time when the flowering was just commencing in 1919, on the different types of branches was as follows :—Monopodia : Primary fruiting branches : Axillary vegetative shoots growing on primary fruiting branches : Axillary vegetative shoots growing on the main stem (The growth of vegetative shoots on monopodia, axillary vegetative shoots growing on primary fruiting branches and on axillary vegetative branches on the main stem were not noted) 1 : 1·5 : 0·4 : 1·5.

It must be recognized that there is a large seasonal factor in such a figure, however, and stress must not be laid upon it as characteristic of the strain.

The growth of primary fruiting branches is particularly vigorous in this strain, and is very regular ; as a result they give rise to an exceptionally large number of axillary shoots rising from axils at various points in their length, a very peculiar character in this and other strains which are especially vigorous in the development of such primary fruiting branches. Such axillaries grow much more rapidly than the original fruiting branch and produce several short new fruiting branches, so that they also increase to a considerable extent the rapidity with which the flowers are produced. This is very marked in a year when the rain tends to cause late flowering, and almost disappears in a year of drought.

Generally speaking the characteristics just described are desirable for a type of cotton in the area under consideration. It secures, if there is a dry season, that the flowers formed directly on the vigorous primary fruiting branches should form bolls, and at the same time, if these fall owing to unseasonable rain, there will be at least as many bolls, rapidly formed later, on the special axillary shoots rising from them as described above. It means, therefore, that the proportion of the total bolls on the plant which are borne on the primary fruiting branches and the axillaries which rise from them is far more constant than could otherwise be the case. The figures actually obtained with the present strain in the two very different seasons of 1918–19 and 1919–20 are as follows : 1918–19 was a year of very severe drought : 1919–20 was a normal season, except for late rains in January.

Proportion of total bolls in the plant which are borne on primary fruiting branches and their axillaries.

	Per cent.
1918–19	34·3
1919–20	33·1

The special characters of the produce in this strain of cotton are as follows :—

(1) The bolls are intermediate in character between the large tapering and the large spherical type. The opening is complete. The weight of the *kapas* per boll is :—

	Grm.
(*a*) 1917–18	2·25
(*b*) 1918–19	1·60 *
(*c*) 1919–20	1·41 *

(2) The *kapas* gave a ginning percentage and lint-index as follows :—

Year	Ginning percentage	Lint-index
1917–18	46·5	4·76
1918–19	49·3	5·23
1919–20	51·5	5·73

The ginning percentage of 1919–20 is probably above the normal for the strain, as part of the first picking was lost owing to late rains. But, in any case, the ginning percentage of this strain is remarkable, and it may be relied on to give between 46 and 50 every year. This is an extremely valuable quality and one of which use can be and is being made in crossing.

(3) The seed was an average *Goghari* size. One hundred seeds weighed as follows :—

	Weight of 100 seeds
	Grm.
1917–18	5·44
1918–19	5·39
1919–20	5·39

(4) The lint is very coarse and poor and gave the following average measurements in 1919–20 :—

	Centimetres
Lint on tip of seed ..	.. 1·40
Lint on middle of seed ..	.. 1·71
Lint on base of seed ..	.. 1·55

The variation from the mean (*a*) at the tip was 9·6 per cent. below, (*b*) at the middle 10·3 per cent. above, and (*c*) at the base it was exactly the mean value. The lint was, therefore, very uneven on the seed.

The lint in the middle of the seed measured as follows, as determined from one hundred measurements made on seeds. The variation is shown in Fig. 6.

Staple of	1·3 centimetres	.. ..	1
Do.	1·4 Do.	.. ..	0
Do.	1·5 Do.	.. ..	8
Do.	1·6 Do.	.. ..	27
Do.	1·7 Do.	.. ..	28
Do.	1·8 Do.	.. ..	19
Do.	1·9 Do.	.. ..	12
Do.	2·0 Do.	.. ..	4
Do.	2·1 Do.	.. ..	1

* In both these seasons there was a very large amount of shedding of bolls, in 1918–19 owing to the long drought and in 1919–20 to the late rain. These figures are hence not normal.

The staple of E5 is the shortest of all the selected strains, the bulk of the lint at the middle of the seed being only 1·6 to 1·8 centimetres long.

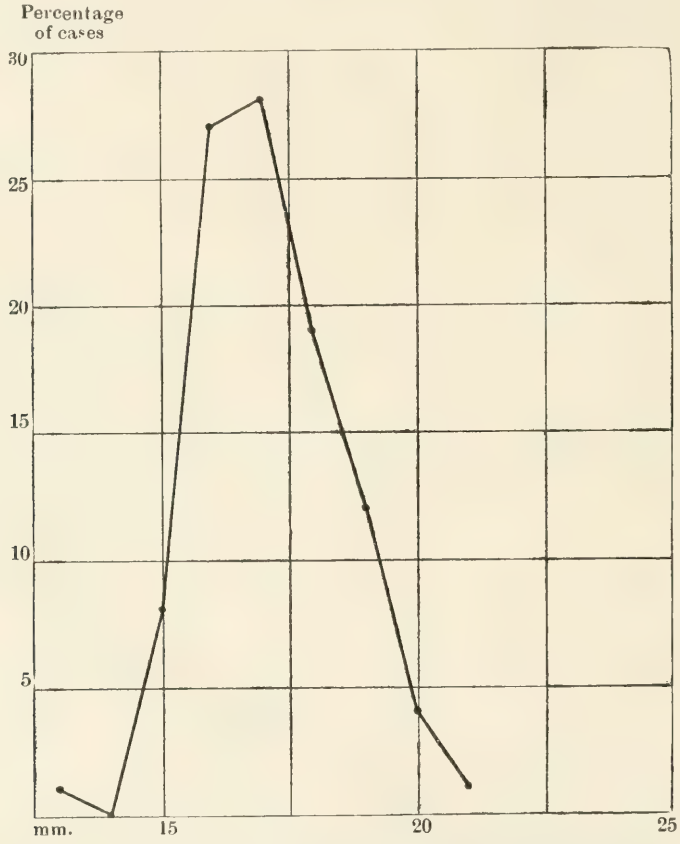


FIG. 6 Variation in length of staple in the middle of the seed in *Goghari* E5. Produced from axillary limbs.

This lint, on examination by Messrs. Tata & Sons, Bombay, gave the following values:—

Year	VALUE OF LINT PER *candy* OF 784 lb.		
	Fine Broach deshi	E5	A26
	Rs.	Rs.	Rs.
1917–18	950	825	..
1918–19	600	450	450
1919–20	500	280	300

On the whole, therefore, the strain may be described as a good yielding one, little affected by the character of the season, giving *kapas* of the highest ginning percentage known among *herbaceum* cottons, though the lint is short, coarse, and uneven. It is likely to have special value for producing a cross with *Broach deshi* cotton. For itself, it is almost worthless.

The relative characters of each of these strains, on the average, for the last two years is shown in the following table. *Fine Broach deshi* cotton is taken as being worth Rs. 500 per *candy*.

Strains	Yield of *kapas* per acre	Yield of lint per acre	Ginning percentage	Value per *candy*	Value per acre
	lb.	lb.		Rs.	Rs.
A26	331	147	44·2	337	63
B3	292	135	46·1	..	..
B21	455	205	44·9	337	88
C22	369	172	46·6	327	72
E5	414	209	50·4	327	87

7. *Comparison of the strains of* Goghari *cotton with pure-bred* Broach deshi *cotton.*

The description just given shows the characters of typical strains of *Goghari* cotton. It is now advisable to put besides them a detailed description of one of the typical strains of *Broach deshi* cotton, which we have isolated at Surat[1], and which breeds true. The strain was selected in ***Navsari*** cotton and has been bred pure under the name "1027 ALF" since 1916-17.

The plant is bushy, bearing a number of monopodia at Surat of 1 to 10, the most frequent number being 6 to 7. Its vigour is less than that found in most *Goghari* cottons and this is particularly the case as regards the development of axillary shoots and branches, and also of primary fruiting branches.

The special characters of the produce of this first class strain of the ***Broach deshi*** cotton are as follows :

(1) The bolls are large and tapering, being very similar to those of *Goghari* B3, except that the surface is smooth and the dark spots are absent. The opening of the bolls is very similar to the most open type of *Goghari*, the recurving at the edges of the valves being only slight. The weight of *kapas* per boll is :—

	Grm.
1917-18	1·29
1918-19	1·49
1919-20	1·39

[1] Surat is forty miles distant from Broach where the *Goghari* types were grown.

This weight is smaller than in any of our strains of *Goghari*.

(2) The *kapas* gave a ginning percentage and lint-index as follows :—

Year	Ginning percentage	Lint-index
		Grm.
1916–17	33·3	2·84
1917–18	33·0	3·10
1918–19	37·3	3·37
1919–20	33·7	2·95

This shows the most obvious difference between the *Broach deshi* type and the *Goghari*.

(3) The seed was on the whole heavier than most types of *Goghari*. One hundred seeds weighed as follows :—

	Weight of 100 seeds
	Grm.
1916–17	5·68
1917–18	6·29
1918–19	6·06
1919–20	5·82

This is, however, not the characterstic of *Broach deshi* as a whole.

(4) The lint is long, fine, and silky, and it gave the following average measurements in 1919–20.

	Centimetres
Lint on tip of seed	2·16
Lint on middle of seed ..	2·69
Lint on base of seed	2·39

The variation from the mean (*a*) at the tip was 9·2 per cent. below, (*b*) at the middle was 9·6 per cent. above, and (*c*) at the base was 0·4 per cent. above. The lint was, therefore, not very different in its variation on different parts of the seed from that of *Goghari*. The lint on the middle of the seeds was varying as follows as determined from 100 measurements made on seeds :—

Staple of	2·1	centimetres	..	..	1
Do.	2·2	Do.	..	..	1
Do.	2·3	Do.	..	..	4
Do.	2·4	Do.	..	..	15
Do.	2·5	Do.	..	..	17
Do.	2·6	Do.	..	..	20
Do.	2·7	Do.	..	..	17
Do.	2·8	Do.	..	..	17
Do.	2·9	Do.	..	..	6
Do.	3·0	Do.	..	..	2

The staple is hence very much longer than that of any *Goghari* strain we know, the bulk of the lint at the middle of the seed being from 2·6 to 2·7 centimetres in length. This is illustrated in the figure below :—

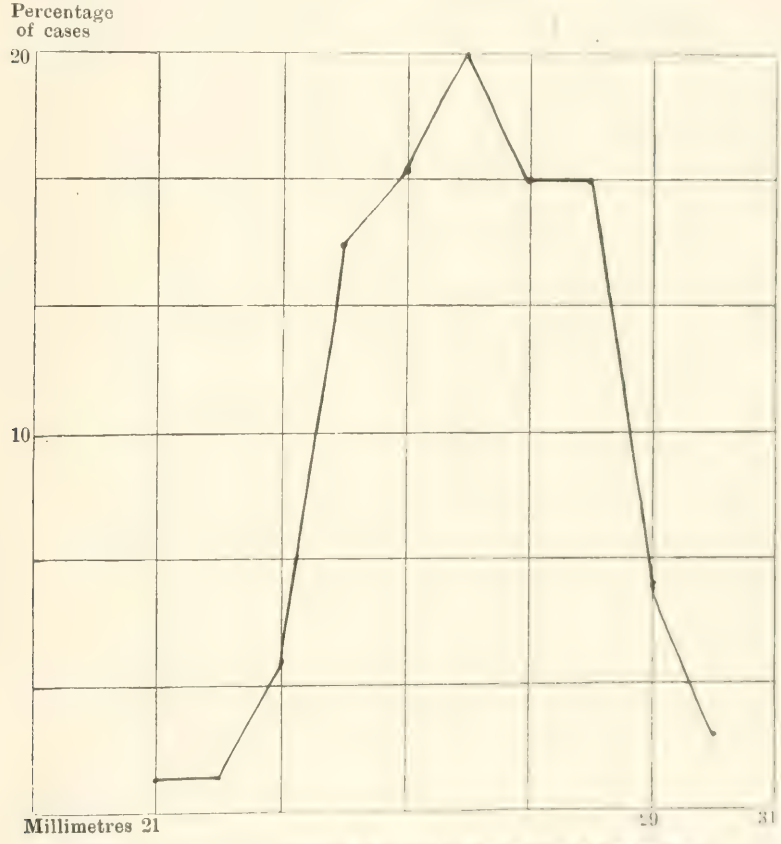


FIG. 7. Variation in length of staple on the middle of the seed in 1027 ALF.

The lint on examination by Messrs. Tata and Sons, Bombay, gave the following values :—

Year	Value of lint per candy of 784 lb.		
	Fine *Broach deshi*	1027 ALF	*Goghari* A26
	Rs.	Rs.	Rs.
1917–18	950	1,089	
1918–19	600	762	450
1919–20	500	550	300

On the whole, therefore, if we compare this representative strain of the best *Broach deshi* cotton with the several *Goghari* strains which we have described, we have as shown in the attached table :—

Characters	*Broach deshi*	*Goghari*				
	1027 A L F	A26	B3	B21	C22	E5
(1) Number of monopodia	6–7	4–5	4–5	6	4–5	3–4
(2) Opening of bolls	Complete valves slightly recurved	Complete. No recurving	Complete. No recurving	Very complete. No recurving	Very incomplete. No recurving	Complete. No recurving
(3) Weight of *kapas* per boll in grm.	1·36	2·12	1·98	1·82	1·73	1·75
(4) Ginning percentage	34·3	44·2	46·1	44·9	46·6	50·4
(5) Lint-index in grammes	3·06	4·87	5·0	4·45	4·56	5·48
(6) Weight of 100 seeds in grammes	5·94	6·17	5·84	5·47	5·22	5·39
(7) Staple of lint at middle of seed in centimetres	2·69	2·01	1·94	1·96	1·91	1·71
(8) Relative value in 1920 per *candy* in Rs.	550	300	..	300	280	280

III. The ideal type of *herbaceum* cotton for Lower Gujarat.

Although the climate and soil conditions are sufficiently varying to make it probable that strains of cotton with somewhat different characters will furnish the best and most profitable types of cotton for different areas in Lower Gujarat, yet there are certain features, which our inquiries reveal which ought to be possessed by a cotton plant, which can be considered, as in any way satisfactory in any part of the area specified. These characters we shall have to describe, but before doing so, it is perhaps necessary to insist on two or three preliminary considerations.

It goes without saying, in fact, that any plant which is selected must be pure, and if possible consist of a pure line. This necessity has never really been adequately realized by growers or by traders, and as a result we have at present a mixture of types everywhere, some of which are suitable to the tract while some are not ; some give good staple cotton, some on the other hand are poor ; some give high, some low ginning percentage. Thus apart from any regular mixture of the three varieties previously noted, we have very extensive admixture of strains of cotton everywhere, which are of extremely different agricultural and commercial value. We wish to insist on this point because it is often supposed that provided the *Goghari* and *Wagad* types are eliminated, the *Broach deshi* which remains will be uniform and of high quality. This is by no means the case, and it is necessary that there should be available definite pure strains of the best variety of cotton for each tract which can be grown with certainty of the quality of the produce. This is not the case at present even when the so-called pure *Navasari* or *Surat* staple cotton is grown.

The second necessity of an ideal type of cotton is that the staple and ginning percentage should be as high as possible, consistent with a good yield of *kapas*. Up to the present, the possession of good staple has been considered as likely to occur with a cotton giving a poor ginning out-turn and generally poor yield in the field. All the definite evidence, however, would seem to indicate that there is no necessary connection between high staple and either low ginning percentage or low yield. With regard to the latter point an experiment was made in 1908–09[1] of transferring large quantities of *Broach deshi* seed from Navsari to Ahmedabad for cultivation. This, though the best stapled seed in the province, is in its own home a very low yielder, but at Ahmedabad it proved to be equal to local types of *Broach deshi* in this respect. Its ginning percentage remained lower than that of

[1] *Annual Report, Surat Agricultural Station*, 1908–09, p. 62.

the local types grown, but there was no complaint that it did not yield equally well.

With regard to the supposed connection between staple and low ginning percentage, the negative evidence is still more clear, and we have succeeded in obtaining strains of cotton which are at the same time of better staple than that usually grown, and which give a large ginning out-turn. The following table shows the average for ordinary ***Surat*** (*Broach deshi*) cotton grown at Surat in these particulars together with the figures for three strains which have been selected from it in 1919–20 :—

Type of cotton	Staple on middle of seed	Gignning percentage
	cm.	
Pure *Surat* cotton average	2·30	33·1
Selection 1A (cylindrical boll)	2·56	37·6
Selection 1A (long boll)	2·50	39·1
Selection 1027 ALF	2·61	33·9

These figures prove that an increase in staple and ginning percentage may be obtained at the same time, and if this is the case, it opens up possibilities for the development of cottons in both directions, hitherto not adequately realized.

But if we get pure cotton of the maximum ginning percentage and the greatest possible length of staple, there are certain characters in the plant in Gujarat *herbaceum* cottons which seem to be needed in order to obtain the best yield of bolls and hence of *kapas* under the climatic conditions of Lower Gujarat. To make the matter more clear, we may note that these cottons are sown in June and are reaped in January to March of the following year. Fairly general rain may be expected in a normal year until early October, with occasional showers later, though sometimes considerable rain falls after this time.

These characters are as under :—

1. The plants must be able to resist heavy rain when very young, that is to say, when they have less than six leaves. The character of the rainfall as well as the soil in Lower Gujarat is peculiar. The soil over the greater part of the cotton growing tract is of a heavy black type. Now this cannot be protected against excessive rains by being formed into small ridges, for the slimy character of the wet soil causes such ridges to disappear very quickly if the rapidity with which the rains come is such as to over-saturate the soil.

And the rain in the latter part of June and especially in the early part of July at Surat, for example, is such that excessive falls are very frequent ; if the plants are on small ridges these latter disappear and the plants are covered up ; if they are on the flat they are drowned by being compelled to remain in water-logged soil temporarily. Hence every year the mortality among the cotton plants is considerable and very often whole fields have to be resown. Some strains resist this drowning better than others. Among *Broach deshi* strains, we have one (Selection 1 A, cylindrical boll type plant) which resists better than any other we know. Similarly one of the strains of *Goghari* previously described (B21) is equally good in this respect.

2. The plants must possess the largest number of monopodia, *i.e.*, the vegetative branches formed in the lower part of the main stem, the number and vigour of which very largely determine the bushiness of the plant. They give rise to secondary fruiting branches, which bear a considerable proportion of the yield of the cotton plant in Gujarat, and as the flowers on these shoots generally appear at a time when they are not likely to be spoiled by rain, it is very important that they should be encouraged to the greatest possible extent. That there is a probable relationship (other things being equal) between the number of monopodia and yield is shown by the following figures for three strains of *Broach deshi* cotton at Surat in 1920, which differ markedly in this respect.

Strain	Number of monopodia	Yield of *kapas* per acre
		lb.
1 A cylindrical boll type	6	756
C1	5	693
1027 ALF1[3]	4	517

This difference will be less marked in a very dry year as in 1918–19, but in a normal year such as occurs in eight years out of ten, the above figures will indicate what will certainly happen.

The reason of the advantage which the strain with many monopodia will show, lies in the fact that the cotton is planted in June and on account of the rain it is not desirable that flowers should appear in large numbers before the middle of November. We refer to this matter again under item 4 below.

3. *There should be the maximum development of vegetative branches on the plant (monopodia and axillary vegetative shoots arising from the main stem.*)

This is illustrated by the following figures, in which in 1919–20 we have measured the total growth of the vegetative branches in nodes, in three strains and compared them with yield.

Strain	Total growth of vegetative branches in nodes	Yield of *kapas* per acre
		lb.
1A cylindrical boll type ..	4,318	756
C1 type	3,863	693
1027 ALF	3,595	517

While these figures are not enough to prove absolutely the connection, yet they indicate the direction in which high yield is to be found in Gujarat.

4. Flowering should not commence till November 15th and should be completed before the end of January.

The reason for this is that before the middle of November fine weather cannot be relied upon, and if rain or cloudy weather occurs, there is a very large shedding of flower buds. Hence it is wise to have a plant, if this is possible, which does not produce many flowers before that time. The flowering must be completed before the end of January, because the whole harvest must be made before the end of March as, owing to the very high temperature during March, April, and May in Gujarat, there is a very large shedding of the immature bolls which remain on the plants. The most favourable time for the flowers to form is from the middle of December to the middle of January.

5. The bolls should be large and should open completely. The size of the bolls is a minor point but does lead to cheaper and easier picking. The complete opening of bolls makes picking so much easier that it is a matter of considerable importance.

These characters are not met with to an ideal extent in any of the cottons now cultivated. The nearest to them at present is reached perhaps in the 1A long boll type above referred to, and in some respects in 1027 ALF of *Broach deshi,* which is particularly suited for the Navsari area. These are hence being now multiplied on a large scale. But

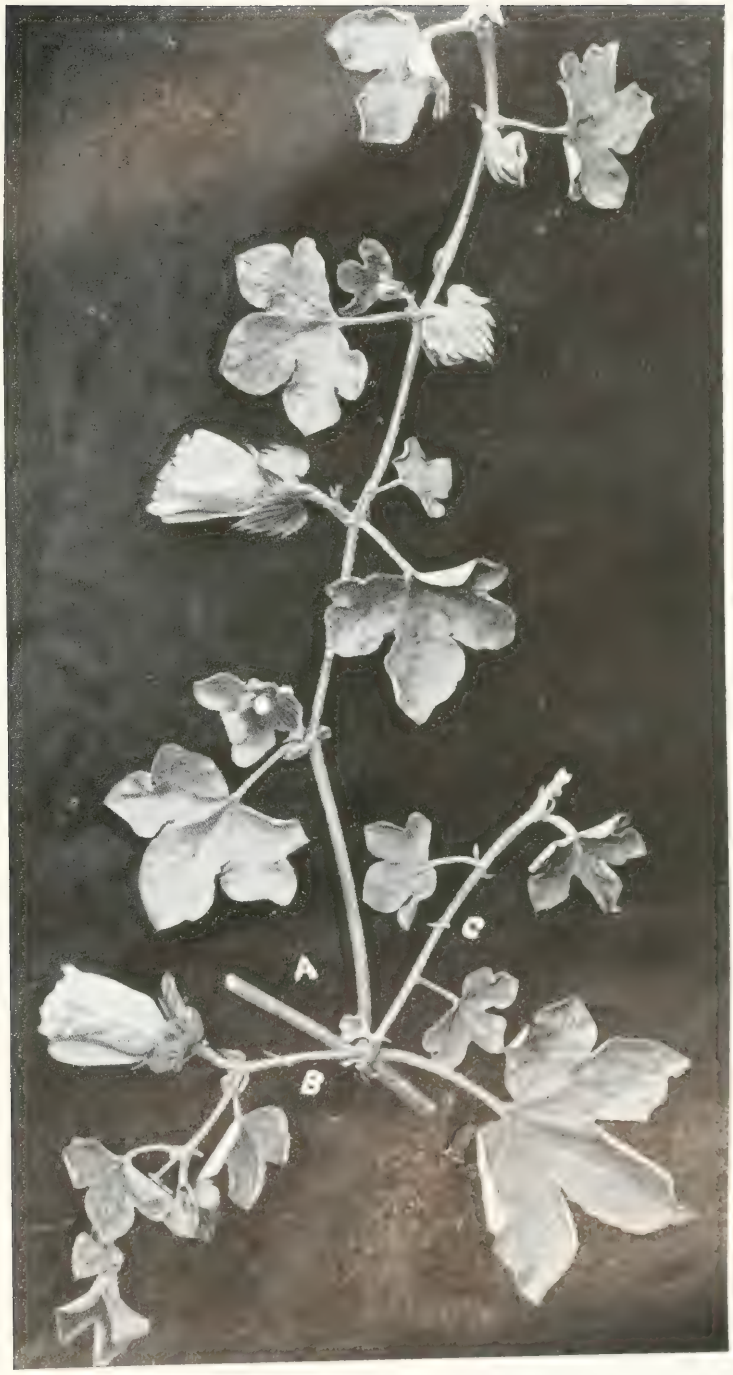
Position of the accessory bud, right.

1, Primary fruiting branch with a flower at the third node. The spiral is against the hands of a watch.

2 & 4, Primary fruiting branches with a flower at the second node ; the spiral is by the hands of a watch.

1 A, Tertiary axillary limb having tertiary fruiting branch with flower at first node. The spiral is against the hands of a watch, *i.e.*, similar to (1) as it is at odd node.

2 A & 3 A, Primary accessory-fruiting branches with the flower at the first node; the spiral by the hands of a watch, even though at odd node (*i.e.*, opposite to 1A and 1).



A shoot. The axil of a leaf having a primary fruiting branch, A; accessory primary fruiting branch, B; and axillary vegetative branch, C; position of the accessory bud, left.

A. Flower at the second node; spiral of the flower against the hands of a watch.

B. Flower at the first node and still the spiral is against the hands of a watch, because it is directly from the accessory bud.

they are nevertheless deficient in some of the characters most to be desired, and if the ginning percentage could be built up by crossing with one of the *Goghari* strains, it is possible that new strains superior to either could be obtained. It is in this direction that work is now being largely done and in which future progress towards the ideal is now likely to be achieved.

ACKNOWLEDGMENTS.

I am under very considerable obligations to Dr. H. H. Mann, who drafted this paper from the results worked out by me.

APPENDIX.

CERTAIN MORPHOLOGICAL CHARACTERS IN *GOSSYPIUM HERBACEUM.*

1. The fate of accessory buds occuring in the axils by the side of primary fruiting branches in *Gossypium herbaceum,* may be of several kinds ; either such accessory bud may remain dormant as occurs in a good many of the buds near the base of the cotton plant, or it may develop into an axillary vegetative branch and this is what usually happens in the middle part of the main stem of the plant. There is, however, a third possibility that these accessory buds should develop directly into primary fruiting branches so that there would be two such primary fruiting branches arising from one axil. This third possibility has never been noticed on Indian cottons ; indeed Leake[1] has definitely stated that this does not occur in Indian types and that the branch from the accessory bud is never sympodial.

Burt and Haider[2] have found the character common however in Cawnpore-American cotton and they state that flowering branches are found to arise from flowering branches. This character is inherited regularly and appears in all plants of a race though in a varying degree and, when well developed, is often associated with the appearance of flowering branches from the accessory bud on the main stem, on the monopodia, as well as on the axillary vegetative branches near the top.

We have found that the phenomenon in question is very common also among plants of *Gossypium herbaceum* grown at Surat. A doubt might occur, however, as to the nature of these shoots arising from the accessory buds especially as Leake classifies such cases as apparent exceptions and state that they can be traced to local damage. That this is not the case, can, however, be clearly proved by a consideration of the æstivation of the flowers on the two primary fruiting branches arising from the main and accessory buds in the same axil, which should always be in the opposite direction to one another.

[1] Leake and Ramprasad. "Studies on Indian Cottons, Part I—The Vegetative Characters." *Mem. Dept. Agri. India, Bot. Series,* VI, no. 4. 1914 : and also in "Observations on certain Extra-Indian Asiatic Cottons." *Mem. Dept. Agri. India, Bot. Series,* IV, no. 5, 1912.

[2] Burt and Haider. "Cawnpore-American Cotton." *Pusa Bulletin* no. 88. 1919.

If, however, the accessory bud had developed first into a vegetative branch however small, which had then given rise to a sympodium, the æstivation of the flower on such a sympodium would be in the same direction as on the primary fruiting branch arising from the main bud. In all the cases which we have examined, and such cases are very common in the upper part of the plant at Surat, the æstivation of the flowers is found to be in the opposite direction on the two primary fruiting branches arising from the node in one axil. This proves, we think, that in *Gossypium herbaceum* at Surat at any rate, both buds in an axil may form sympodia. Illustrations of such occurrences will be seen in Plates VII and VIII.

The following example will make the point clear :—

Suppose that the position of the accessory bud is on the right side of the main bud. The æstivation of the flower at the first node of the fruiting branch developing from the main bud, will be against the hands of a watch, while the æstivation of the flower at the first node of the fruiting branch developing from this accessory bud will be in the same direction as the hands of a watch.

In the case of the flower at the second node of the fruiting branch developing from the main bud it will be in the same direction as the hands of a watch, while in the case of the flower at the second node of the fruiting branch developing from the accessory bud, the æstivation will be against the hands of a watch. This rule is applicable at all further nodes.

The opposite is the case in both sorts of branches when the position of the accessory bud is on the left of the main bud.

2. *The leaf-factor.* In connection with the various species of *Gossypium*, the term "leaf-factor" was introduced by Leake[1] in order to define by a single figure the relationship between the breadth of the middle lobe of the leaf and the indentation of the leaf, and though some doubt has recently been raised by Kottur as to its simple character, yet it is a convenient figure for the purpose in question. There is a good deal of interest attached to the consideration as to how the shape of the leaf as thus described varies on different parts of the plant, and Leake has stated that in his observations the leaf-factor of the leaves on the primary fruiting branches is the smallest, on the main stem somewhat greater, while on the monopodia it is the largest of all. This relationship applies, according to Leake, to all types of cotton which he has examined.

So far as various strains of *Broach deshi* and *Goghari* types of *Gossypium herbaceum* grown at Surat and Broach are concerned, we have found, however,

[1] *Journal of Genetics*, 1, p. 220, 1910–11,

results which differ slightly from those noticed by Leake. According to our observations, while the leaf-factor of the leaves on the primary fruiting branches is the smallest (as Leake states) the leaves on the main stem themselves vary a good deal and the results differ with different varieties. While the leaves on the lower part of the main stem in *Broach deshi* have a smaller leaf-factor than those on the monopodia, those on the upper give a higher figure. In *Goghari*, on the other hand, our figures indicate that it is larger on the leaves of the main stem. The average figures for the different types of leaves in 1919–20 are as under :—

	Leaf-factor.	
	Broach deshi strains	*Goghari* strains
Primary fruiting branches	1·08	0·92
Lower portion of the main stem	1·14	1·14
Upper portion of the main stem (Leaves above the 15th leaf)	1·38	1·17
Monopodia	1·24	1·08

3. *Growth period of various types of branches.* There are, as has been frequently noted in connection with the cotton plant, four types of branches in connection with which flowers and bolls may be formed. The period of flowering and the length of time that the flowering lasts depends very largely on the relative development of each of these types of branches and hence it is of some importance to ascertain the growth period of each type as one of the factors which determines the yielding capacity of the plant. The various types of branches involved are :—

(1) The primary fruiting branches or sympodia.

(2) The monopodia or primary vegetative branches which bear secondary fruiting branches.

(3) The axillary vegetative branches occurring in the axil of the leaves on the main stem, by the side of the primary fruiting branches, which also bear fruiting branches.

(4) The axillary vegetative branches occurring in the axils of the leaves on the primary fruiting branches, which also themselves bear fruiting branches.

Now the first flowering in this type of cotton occurs on the primary fruiting branches, the next on the fruiting branches arising from the monopodia, and last come the flowers borne in connection with the axillaries. It has been stated by Leake[1] that, in his experiments on this type of *herbaceum* cotton, the vegetative period or the period between sowing and the appearance of the first flower was about 207 days, and he draws the

[1] *Mem. of the Dept. of Agri. India, Bot. Ser.*, VI, no. 4 (1914).

contrast between this and the corresponding period in the sympodial cottons where it is 80 to 90 days.

So far as Gujarat is concerned and with *Broach deshi* variety, we find that this vegetative period is much shorter than is stated by Leake. In 1918–19, when the long drought and low rainfall gave an opportunity for the first formed flower buds to develop, the vegetative period for *Broach deshi* strains was only 120 days.

In 1919–20, however, when owing to rain and bollworm attack, the first formed flower buds were destroyed, the period extended to 135 days. But both of these figures are far below that given by Leake, and it is probable that the exact time is very largely a matter of climatic conditions under which the cotton is grown.

The period during the growth of a *Broach deshi* plant required by the first branches of each kind as appeared at Surat, was as under in 1918–19 and 1919–20 :—

The first monopodium appeared in both years between 1 to 1½ months after germination ; the first primary fruiting branch was noticed between 1½ to 2 months ; the first axillary vegetative branch on the main stem appeared after 2 to 2½ months growth ; and the first axillary vegetative branch on the primary fruiting branches appeared after 4 to 4½ months.